

METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR OCTOBER, 1954

Vol. 50

No. 300

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.

Telephone: BLAckfriars 2084

London Office:

50, Temple Chambers,
Temple Avenue, E.C.4.
CENTral 8914

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Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—24/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

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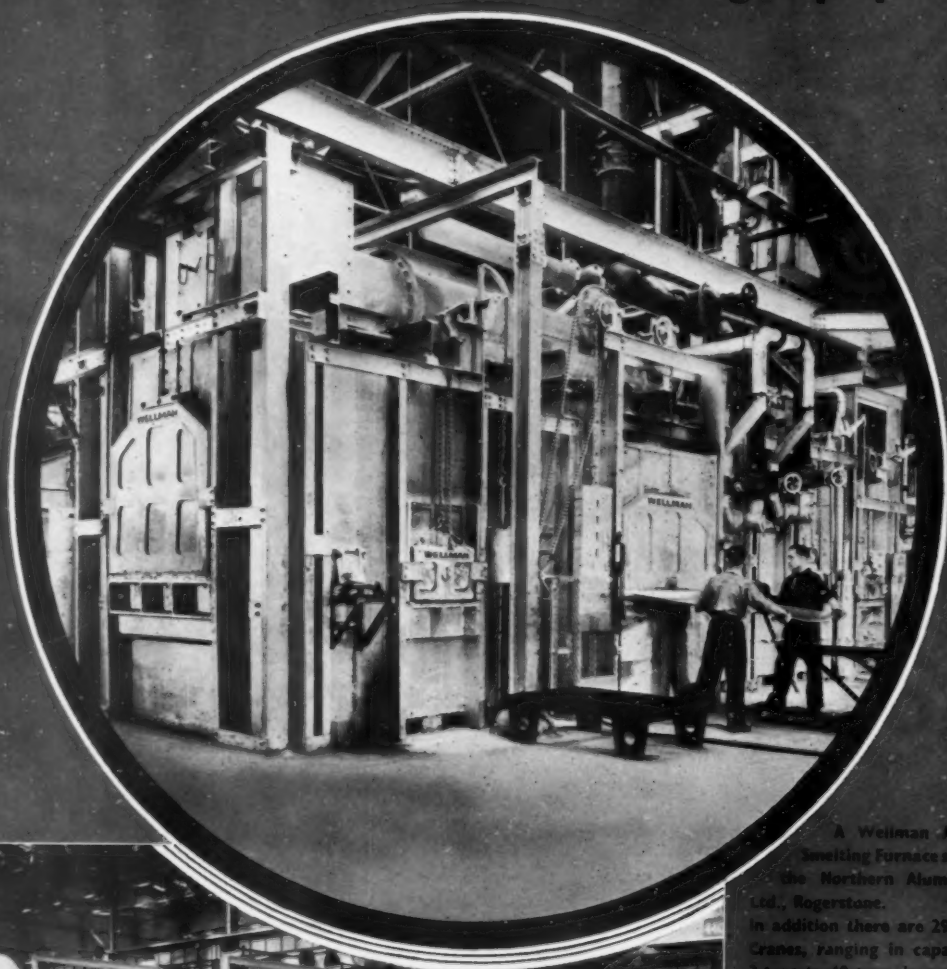
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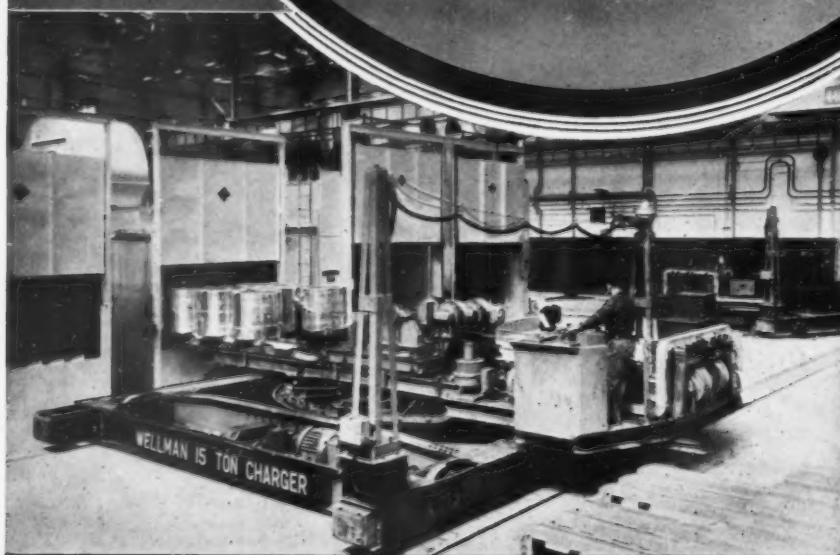
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METALLURGIA

THE BRITISH JOURNAL OF METALS
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October, 1954

Vol. L. No. 300

Research in Europe and U.S.A.

IT is perhaps not inappropriate that in an issue in which are surveyed the activities of a number of research associations based on the metallurgical and allied industries, consideration should be given to the subject of applied research in general. There has been published recently a three-volume report on The Organisation of Applied Research in Europe, the United States and Canada.* Volume I provides a comparative study, whilst the second and third volumes deal in some detail with the European and United States and Canadian aspects, respectively.

Even in the absence of exact and comparable data which would help countries to judge the size and efficiency of their own research effort in the light of their national requirements, it is clear that most countries would benefit from an expansion of their research effort, and from a close scrutiny of their policy on research personnel and their arrangements for co-operation, co-ordination and information exchange. Problems which lie at the root of the matter are the lack of sufficient qualified personnel and their effective use, and the lack of adequate funds, both in support of the research personnel and for the commercial application of the results achieved. It is also vitally important that both management and the general public should appreciate the importance of research and its results for increased production and a higher standard of living.

There is little doubt that conditions in America are more favourable for applied research and industrial innovation. There, research has a certain prestige, is acknowledged as a full partner with Government and industry, and is encouraged to play its full part in the development of national and industrial prosperity. Capital for innovation is more freely available than in Europe, and there is a direct and down-to-earth approach to the problem of applying and exploiting research results. It would be to the practical advantage of European countries if they could foster the same enthusiasm for research in patrons, clients, and the ultimate consumers of the products. There is no lack of research quality in Europe, what is needed is more frankly commercial initiative on the part of the applied scientist, and more direct support and recognition of the production and profit potentialities by industry and Government.

There is a temporary lack of balance in most countries between the efforts devoted to fundamental and to applied research. In Europe, the remedy lies in strengthening the applied side and concentrating on speedier application of research results. As mentioned earlier, this involves making available a freer supply of investment capital, and reviewing fiscal policy in relation to

research and innovation. In the United States the problem is reversed, in that fundamental research and teaching facilities need reinforcement. There, the effects of the lack of balance will be slower to make themselves felt, but as a long-term policy, it is essential that they should be faced now.

Governments are to-day tending to take on larger financial and operational responsibilities in both education and research, but all concerned are anxious to ensure that Government support, though necessary, does not stultify creative effort or unduly restrict academic or research freedom.

Outside direct Government research and the research carried out in the laboratories of private industrial concerns, there are two distinct lines of approach to the problem of meeting the research needs of industry. In Europe generally and in Canada, where there is a large proportion of small firms, the emphasis is on stimulating co-operative research organisations. In the United States, on the other hand, despite a roughly similar overall industrial pattern, more emphasis is placed on sponsored research institutes, although trade associations and other industrial organisations support a considerable volume of co-operative research work in their own or independent research laboratories. The suggestion is made—and this is not likely to meet with unqualified approval—that European co-operative research organisations should also undertake a proportion of contract work, and provide the same service as the American sponsored research institute, care being taken to ensure that the research programme does not become unbalanced through accepting too many *ad hoc* research projects.

Reference has already been made to the retarding effect of the shortage of trained manpower, and if adequate supplies of qualified research personnel are to be forthcoming, more financial support will have to be given to Universities and Institutes of Technology, so that they can provide the necessary teaching facilities and adapt their curricula to current and future needs. In Europe this means more support for departments of technology; in America more support for departments of fundamental science.

Considerable care should be taken in recruiting staff to ensure that they are suited to the requirements of the research programme and are given appropriate conditions for their individual specialities. Consideration should also be given to the appropriate ratio of qualified to less qualified research personnel, a ratio which in Europe particularly appears unduly high. Remuneration should be related to scientific value and not exclusively to administrative or rather more practical ability. What is perhaps even more important, there should be reasonable parity in the salaries of professional, technical, teaching and research staffs; otherwise industry may gain its recruits at the expense of the workers in the education and fundamental research fields, thus cutting off its supply of both trained personnel and ideas for development.

* The Organisation of Applied Research in Europe, the United States and Canada: Vol. I—A Comparative Study (6s.); Vol. II—Applied Research in Europe (12s.); and Vol. III—Applied Research in the United States and Canada (8s.) Published by the Organisation for European Economic Co-operation and obtainable through the agency of H.M. Stationery Office.

Forthcoming Meetings

22nd October

West of Scotland Iron & Steel Institute. "The Encouragement of Productive Research," by DR. J. H. CHESTERS. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

25th October

Institution of Production Engineers (Sheffield Graduate Section). "Shell Moulding," by D. N. BUTTREY. Royal Victoria Station Hotel, Sheffield. 6.30 p.m.

26th October

Incorporated Plant Engineers. "Heatless Repair of Broken Castings," by a representative of Mullard, Ltd. Leeds University. 7 p.m.

Sheffield Metallurgical Association. "Modern Precision Weighing," by DR. G. I. HODSMAN. Arranged by Methods of Analysis Group. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

27th October

Institute of British Foundrymen—Birmingham Branch. "The Production of Heavy Steel Castings," by S. TAYLOR. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 7.15 p.m.

Manchester Metallurgical Society. "Metallurgical Problems of Atomic Energy," by DR. H. M. FINNISTON. Lecture Room, Central Library, Manchester. 6.30 p.m.

1st November

East Midlands Metallurgical Society. "Extrusion of Light Alloys." To be arranged by the Institution of Metallurgists. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7.30 p.m.

Institute of British Foundrymen (Sheffield and District Branch). "Castings versus Fabrications," by H. MOTTRAM. College of Technology, Pond Street, Sheffield. 7.15 p.m.

2nd November

Institute of Metals—Oxford Local Section. "Ceramics," by DR. J. WHITE. Ballroom of the Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Sheffield Metallurgical Association. "Some Theoretical Aspects of Practical Rod Rolling," by E. W. GREGORY, B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

3rd November

Institute of British Foundrymen—Burnley Section. "An Approach to the Mechanized Production of Moulds," by J. HILL. Municipal College, Ormerod Road, Burnley. 7.30 p.m.

Institute of British Foundrymen—Lancashire Branch. "Some Aspects of High Duty Cast Iron" and "Is Green Sand Moulding Deteriorating?" by C. R. VAN DER BEN and H. HAYNES, Engineers' Club, Albert Square, Manchester, 1. 7 p.m.

Institute of Welding. "Spot Welding of Light Alloys," by J. E. ROBERTS. Reynolds Hall, College of Technology, Manchester. 7.15 p.m.

Institution of Engineering Inspection. "The Reclamation of Porous Castings by Impregnation," by P. J. YOUNG. Room 3, Birmingham Chamber of Commerce, New Street, Birmingham. 7.30 p.m.

4th November

Incorporated Plant Engineers. "Metal Spraying," by W. E. BALLARD. Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough. 7.30 p.m.

Institute of Metal Finishing. "Heavy Electro-deposits for Engineering Purposes," by A. W. WALLBANK. The Engineers' Club, Albert Square, Manchester. 7.30 p.m.

Institute of Metals—Birmingham Local Section. "Metallurgical Research in the Electrical Industries," by DR. I. JENKINS. James Watt Memorial Institute, Great Charles Street, Birmingham. 6.30 p.m.

Institute of Metals—London Local Section. "Trends in Metallurgy," by PROF. A. G. QUARRELL. Royal School of Mines, South Kensington, London, S.W.7. 7 p.m.

8th November

Institute of Metals—Scottish Local Section. "Some Metallurgical Problems in Welding Non-Ferrous Metals," by P. T. HOULDCROFT. 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

8th November

Institute of Welding (Sheffield and District Branch). "The Influence of Welding in the Use of Steel," by S. M. REISSER. Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield. 7.15 p.m.

Institution of Production Engineers (Sheffield Section). "Boron Steels," by R. WILCOCK. Grand Hotel, Sheffield. 6.30 p.m.

9th November

Institute of Metals—South Wales Local Section. "Some Aspects of Creep," by DR. J. P. DENNISON. Metallurgy Department, University College, Singleton Park, Swansea. 6.45 p.m.

Sheffield Metallurgical Association. "Open Hearth Furnaces: (ii) Basic Roofs." Arranged by Refractories Group. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

10th November

Manchester Metallurgical Society. "X-rays in Metallurgical Research," by DR. E. A. CALNAN. Lecture Room, Central Library, Manchester. 6.30 p.m.

11th November

Institute of British Foundrymen—Beds./Herts. Section. "Patterns with Special Reference to Pressure Cast Aluminium Plate," illustrated by lantern slides and sample patterns, by B. PERRY. Small Assembly Room, Town Hall, Luton. 7.30 p.m.

Institute of British Foundrymen—Southampton Section. "Solidification of Metals," by A. PRINCE. Technical College, St. Mary's Street, Southampton. 7.30 p.m.

12th November

Institution of Mechanical Engineers. "Inspection, Explosion and Breakdown of Boilers and Pressure Vessels," by J. EYERS. 1, Birdcage Walk, Westminster, London, S.W.1. 5.30 p.m.

Society of Chemical Industry, Corrosion Group. Discussion of Practical Corrosion Problems of Industries of the South West. "Corrosion-resisting Metals for Marine Applications," by L. KENWORTHY; "Protective Coatings," by W. E. BALLARD; "Plastic Coatings and Linings," by F. F. JARAY. (Joint Meeting with the South-Western Section). The Technical College, Plymouth. 2.30 p.m. and 6.30 p.m.

13th November

Institute of British Foundrymen—Newcastle Branch. "Dust Problems in Foundries," by W. H. WHITE. Neville Hall, Westgate Road, Newcastle-on-Tyne. 6 p.m.

Institute of British Foundrymen—West Riding of Yorkshire Branch. "Moulding," by L. L. ALLARD. Technical College, Bradford. 6.30 p.m.

15th November

Institute of British Foundrymen—Birmingham Branch. "The Hardening of Moulds and Cores by the CO₂ Process," by DR. D. V. ATTERTON. James Watt Memorial Institute, Great Charles Street, Birmingham, 3. 7.15 p.m.

16th November

Institution of Engineers and Shipbuilders in Scotland. "The Choice of Electrodes for Ship Welding," by G. ZOETHOUT. 39, Elmbank Crescent, Glasgow. 7.30 p.m.

Sheffield Metallurgical Association. "Specifications—Friends or Foes," by S. BARRACLOUGH. Joint Meeting with the Society of Engineers and Metallurgists and The Institute of Metals. B.I.S.R.A. Laboratories (Sheffield Group), Hoyle Street, Sheffield, 3. 7 p.m.

17th November

Institute of British Foundrymen—London Branch. "Some Foundry Problems," by G. ROGERS. Waldorf Hotel, London, W.C.1. 7.30 p.m.

Institute of Fuel (Yorkshire Section). "Flame Radiation Research," by PROF. M. W. THRING. Royal Victoria Station Hotel, Sheffield. 2.30 p.m.

Institute of Welding. "Structural Engineering—Some Aspects of Welding," by E. R. WHITTY. Technical College, Bolton. 7.15 p.m.

Institution of Engineering Inspection—Wolverhampton Branch. "Shell Moulding," with a demonstration of the Process, by M. C. DIXON and R. S. BUSHELL. Compton Grange, Compton Road, Wolverhampton. 7.30 p.m.

Spheroidal Graphite Formation

By E. Ward, A.C.T.(Birm.), A.I.M.

Although cast iron in which the graphite occurs in the spheroidal form in the as-cast state is now an accepted engineering material, and although a considerable amount of research has been carried out on the mechanism of spheroidal graphite formation, there are still considerable differences of opinion on the subject. In the present article the author discusses the various theories that have been put forward.

FOLLOWING upon the first announcement of the consistent production of spheroidal graphite in the as-cast state by Morrogh and Williams in 1947,^{2,3} a considerable amount of fundamental work has been carried out on this phenomenon, and many theories have been advanced to account for it. The aim of this paper is to tabulate the more important facts and theories that have evolved, in the hope that it may in some way be a step towards a truer understanding of the principles involved.

Methods of Obtaining Spheroidal Graphite

The two established methods of producing spheroidal graphite cast iron involve treatment with magnesium or cerium. In both cases the molten iron to be treated should be of such composition as to solidify grey under normal conditions, and the addition of magnesium or rare earth metals must be sufficient to reduce the sulphur to very low levels, and to leave an excess of the element or elements in solution. In the magnesium process the sulphur is reduced to 0.01%, or less, and the residual magnesium gives best results when present in quantities between 0.04% and 0.10%, the quantities required in the cerium process being similar.

As magnesium and cerium are very strong carbide-forming elements, it is usually necessary to inoculate with a silicon-bearing alloy, immediately after treatment, to produce a structure free from carbide. The magnesium treatment can be effectively applied to either hypoeutectic or hypereutectic irons, whereas the cerium treatment is only effective with a hypereutectic composition.

It has also been stated that calcium in excess of 0.04% is capable of producing spheroidal graphite iron^{1,2} although this process is not yet of industrial importance. Other elements which have been reported to produce a limited amount of spheroidal graphite^{1,3} include titanium, boron, lithium, strontium, barium, sodium, potassium, bismuth, selenium and thorium. Tellurium-treated irons often contain spheroidal graphite near the chilled area. Spheroids have also been obtained by the rapid cooling of pure iron-carbon and high-silicon melts⁴, and by the annealing of white irons with either a high sulphur/manganese ratio, or with residual magnesium.

Interfering Elements

During the development of the magnesium process, a number of elements have been found to interfere with complete spheroidisation of the graphite, although they do not interfere with the cerium process. These elements include antimony, arsenic, bismuth, tin, lead, selenium, tellurium and titanium. Copper also interferes, especially when other subversive elements are present. It will be noted that some elements which cause interference are

also capable of producing limited spheroidisation, these being bismuth, selenium, tellurium and titanium. This anomalous situation tends to suggest that spheroidisation may take place by two or more different mechanisms.

This suggestion is further strengthened by the fact that the elements magnesium, cerium and calcium actually have a cumulative effect on spheroidisation, so that magnesium can be partly replaced by one of the other two. It is in fact known that a small amount of cerium added to a magnesium-treated iron will neutralise the effect of interfering elements.⁵

Important Research Findings

Attempts have been made by a number of research workers to determine the mode of solidification of spheroidal graphite (S.G.) irons, and, although their findings have been in some cases contradictory, some outstanding points are worthy of mention.

By the quenching of irons during the process of solidification, it has been found that in a hypoeutectic iron, the first stage of solidification is the formation and growth of austenite dendrites. This is followed by the formation of graphite in the carbon-rich liquid adjacent to the dendrites in the case of both spheroidal and flake graphite irons.⁶⁻⁸ In the case of spheroidal graphite, a skin of austenite is quickly formed around the growing spheroids, whereas flake graphite appears to grow in clusters with the leading edge of each flake in contact with the liquid, austenite being formed between the flakes. In the case of a completely spheroidal iron, the final solidification of the eutectic liquid occurs by the diffusion of carbon to the existing spheroids with the simultaneous formation of austenite. When an iron is not completely spheroidal however, the last liquid to solidify appears to form mostly austenite and a flake form of graphite. This effect is often visible in the microstructures of imperfectly spheroidal irons, where the flake graphite is concentrated at the grain boundaries (see Figs. 3 and 4). When a hypereutectic iron is treated with cerium, it has been stated that nodules are formed directly from the liquid.⁸

With the gradual increase of spheroidising element in a grey iron, the change from flake to spheroidal graphite is gradual, the flakes becoming shorter and thicker until isolated spheroids begin to appear. This modified graphite differs slightly in form between the cerium and magnesium or calcium treatments. That which occurs in cerium-treated irons is referred to as quasi-flake graphite, in the other two types of iron it is in flake form or compacted flake.⁹ Several slightly differing types of graphite are also found to occur in magnesium-treated irons contaminated by interfering elements, and these are illustrated in Figs. 1 to 5.

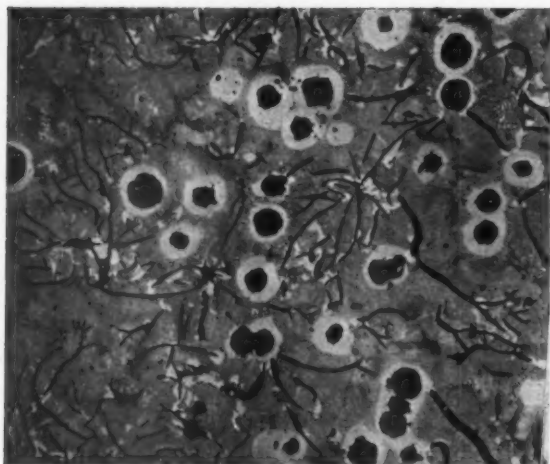


Fig. 1.—Iron containing 0.05% Mg and 0.08% Ti. $\times 100$

Theories Relating to Spheroidal Graphite

The theories concerning the formation of spheroidal graphite may be grouped into two categories, namely:—

- (1) Those stating the location in which the spheroids commence to grow, i.e.,
 - (a) in supersaturated austenite;
 - (b) on first-formed carbide particles;
 - (c) in the liquid adjacent to the first-formed austenite dendrites.
- (2) Those attempting to explain the cause of spheroidal growth, i.e.,
 - (a) nucleation by a compound of magnesium;
 - (b) removal of the flake graphite nucleus resulting in super-cooling, which is stated to favour the growth of spheroids;
 - (c) reduction of the wetting properties of molten iron for graphite;
 - (d) absorption of the spheroidising element into the first formed graphite affecting the subsequent growth.

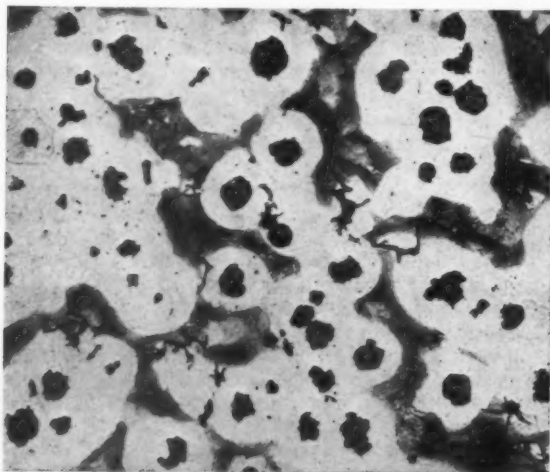


Fig. 2.—Iron containing 0.072% Mg and 0.003% Bi. $\times 100$

Group 1

To consider first the theories in Group 1:

(1a)

The theory that the spheroids form in supersaturated austenite is upheld mainly by De Sy¹⁰ and Wittmoser¹¹ and probably originates from the fact that the spheroid rapidly develops a skin of austenite during growth. Micrographs have been published, however, by Morrogh¹² and others, showing spheroids, formed in hypereutectic irons during the early stage of solidification, which have no accompanying austenite.

It is difficult to understand by what means the austenite becomes supersaturated, as suggested by the theory, because the solubility of carbon in austenite increases quite rapidly with fall in temperature, until the eutectic arrest occurs.

(1b)

The theory that spheroids are nucleated by first-formed carbide has very few supporters, although it is generally recognised that in special cases spheroids can grow by the decomposition of carbide; for instance, in

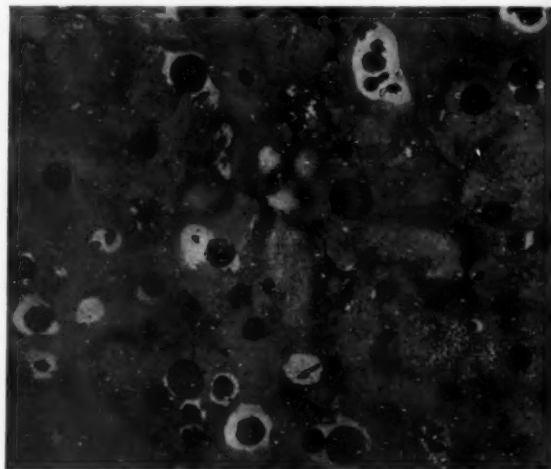


Fig. 3.—Iron containing 0.047% Mg and 0.012% Sb. $\times 100$

a partly annealed white iron containing magnesium, spheroids are often found growing at the austenite-cementite interface. Morrogh has published evidence¹² that spheroids can grow by the decomposition of eutectic carbide during the cooling of an uninoculated iron. On the other hand, however, flake graphite can be formed by the decomposition of carbide in a cerium-treated iron, according to Morrogh and Williams¹³, who also declare that 'undercooled' graphite is formed by this mechanism.

(1c)

The theory that the spheroids form in the liquid adjacent to the growing austenite dendrites, or in the liquid before the formation of austenite in the case of hypereutectic irons, is favoured by Morrogh,¹² Hughes,⁶ and many others, and is based on the microstructures of S.G. irons quenched during solidification. The micrographs published with these papers seem to provide very strong evidence in support of the validity of the theory. It will be realised, of course, that the liquid adjacent to the leading edge of the growing austenite

dendrites will have the highest carbon content and, therefore, be the most likely site for the initial formation of graphite.

Group 2

The theories falling into Group 2 may be more profitably examined in the light of the imperfect structures to which previous reference has been made.

(2a)

The theory of nucleation is an obvious possibility, and was borne out for a while by the presence of a white spot in many spheroids, this however, has been shown to be an optical phenomenon depending upon the plane of intersection of the spheroid.¹⁴

When two or more different graphite forms are present in the same sample it does not seem likely that each form has its own type of nucleus. Furthermore, it is difficult to imagine why approximately 0.075% (atomic) magnesium is required simply to furnish nuclei of a few atomic diameters. A recent paper by Hultgren and Ostberg¹⁵ indicates that in the case of an annealed iron having a high sulphur/manganese ratio the spheroidal graphite is often formed around sulphide inclusions.

(2b)

The theory of the removal of flake graphite nuclei with subsequent undercooling is probably due to the publishing of cooling curves showing that the eutectic arrest of S.G. iron occurs at a lower temperature than that of flake graphite iron, but the lower arrest temperature is more likely to be the effect than the cause of spheroidisation, and is thought to result from formation of the layer of austenite around the growing spheroids. As the rate of diffusion of carbon through austenite must be appreciably lower than the rate of diffusion through the melt, the time required for solidification must be extended, with a consequent drop in temperature. It is, however, true that if real undercooling occurs, then there cannot be any extraneous nuclei present.

If it be accepted that in an imperfect specimen the spheroids form during the early part of solidification and flakes form during the latter part, as previously stated, then only two explanations are apparent. The first is that the flake-forming nuclei are present throughout solidification, and their growth is retarded until the end of the eutectic arrest. The second is that they are formed spontaneously during the final stages of solidification, i.e., in the most severely undercooled portion. Thus neither of these two possibilities tie up with the theory as stated.

As pointed out in 2a, it is unlikely that separate nuclei exist for the several types of graphite; they must, therefore, be modified during growth, possibly by the concentration of certain elements at the grain boundaries.

(2c)

The theory involving the modification of wetting properties of iron for graphite follows on the findings of Buttner, Taylor and Wulff,¹⁶ and other workers. It was discovered that flake graphite iron melted in an atmosphere of helium in a graphite crucible caused wetting of the crucible, whereas S.G. iron treated with magnesium did not. Donoho¹⁷ suggests that the presence of free manganese sulphide affects the wetting properties of the iron. Keverian, Taylor and Wulff¹⁸ consider that impurities such as sulphur and oxygen are absorbed on the graphite surface, and this lowers the interfacial energy.

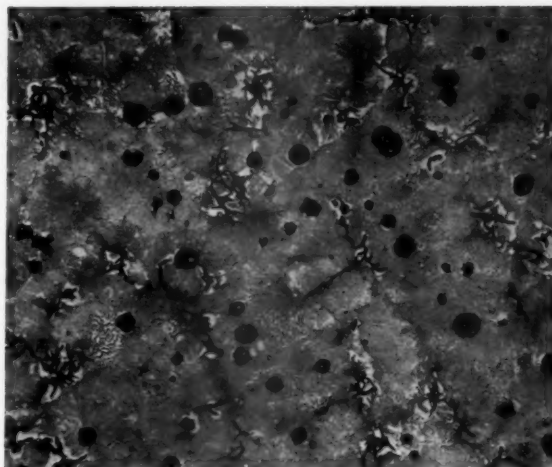


Fig. 4.—Iron containing 0.076% Mg, 0.05% Ti and 2.0% Cu. $\times 100$

This does not, however, account for the fact that annealed high sulphur irons may contain spheroids; unless the formation of spheroids within a solid phase be regarded as a different matter, as well it might.

The production of imperfect structures is still difficult to explain by this theory, unless it be assumed that a change in wetting properties is brought about during solidification. This might be caused by the segregation of impurities to the grain boundaries, but there is no direct evidence yet that this occurs.

If it could be demonstrated that the wetting properties of magnesium-treated irons, when contaminated by interfering elements, were intermediate between flake graphite and fully spheroidal irons, then the theory might become acceptable.

(2d)

The theory that the graphite form is modified by absorption appears to be quite reasonable. One could explain the duplex type of graphite structure by assuming that the spheroidising element is absorbed into the

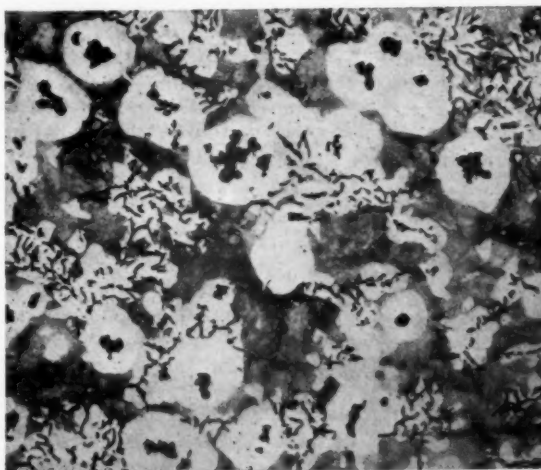


Fig. 5.—Iron containing 0.057% Mg and 0.13% Ti. $\times 100$

first formed graphite but not into that formed during the later stages of solidification, when the interfering elements may be concentrated in the remaining liquid. Both this theory and the one given in 2c could account for the gradual modification of the graphite with increasing amounts of spheroidising additions.

The one important argument against this theory is that no perceptible concentration of magnesium has been detected in the separated and ignited spheroids, although it must be admitted that there is a danger of some magnesium being lost by volatilisation during ignition. Hillert and Lindblom,¹⁹ however, have published autoradiographs of a cerium-treated nickel-carbon alloy which indicate a slight concentration of cerium within the spheroids, and they suggest that spheroidal graphite is formed by screw dislocations produced by absorbed foreign atoms such as cerium and magnesium.

Summary

Although considerable progress has been made towards a fuller understanding of spheroidal graphite formation, there is still a surprising lack of agreement between different authoritative workers on the mode of solidification. The interrupted cooling technique does not appear to be entirely satisfactory in determining the sequence of solidification because there is no guarantee that relevant changes have not occurred during the quench; moreover, the resulting micrographs may allow of more than one interpretation. If X-ray diffraction techniques can ever be applied to molten iron, this may establish with much more certainty the sequence of solidification.

The number of theories relating to the causes of spheroidal growth is a healthy sign of the interest shown in this phenomenon; unfortunately theories are much more easily formulated than verified. It must be realised that very little is known about any type of graphite formation, and it is more than likely that if the fundamentals of normal graphite formation were fully established, an understanding of spheroidal graphite would automatically follow.

Acknowledgments

The author is indebted to The British Cast Iron Research Association for providing the photomicrographs and to the management of Tees Foundries, Ltd., for assistance given in preparing this paper.

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Dorman Long Orders for Davy-United

THE order to build the new blooming mill for the Lackenby Works of Dorman Long has been placed with Davy and United Engineering Co. Ltd. of Sheffield. This mill, a 52 in. × 112 in. reversing blooming and slabbing mill, will be designed to roll ingots weighing from 4.4 tons of 23 in. square section up to 20 tons with a shaped section of 52 in. × 41 in. Its primary purpose will be to produce blooms for subsequent conversion into broad flange beams, ranging in size from 6 in. × 4 in. to 36 in. × 16½ in. It will, however, also roll rectangular or shaped blooms for joists, channels, angles and sheet piling, in addition to slabs up to 50 in. wide.

The mill will be driven by two 4,000 h.p. R.M.S. motors (each 12,000 h.p. peak) and will be equipped with universal manipulators and tilting gear, all necessary main and auxiliary roller tables, ingot tilting chair and ingot weighing equipment. A 1,350 tons hydraulic opensided upcutting bloom and slab shear, with pump and accumulator drive and capable of cutting slabs up to 10 in. × 50 in. or equivalent section up to a maximum thickness of 19½ in., will also be supplied along with approach and run out tables and a nine-chain transfer bank.

The mill, which will have an output of some 15,000 tons/week, will be the largest of its type operating in Britain, and will be the ninth Davy-United blooming and slabbing mill installation to be completed since 1944. The value of the contract is nearly £1,000,000 and the mill is expected to start production in January, 1957. In all, 3,500 tons of new machinery will be involved.

A second order for another section of the Dorman Long development schemes covers the supply of primary cooling banks, complete with all approach and run-out tables, for the Cleveland section mill.

Education-Industry Conference

FORTY-EIGHT university lecturers, representing most of the universities in the country, were the guests of the United Steel Companies Ltd., at a Conference in Sheffield during the week commencing September 6th. The aim of the Conference was to give an insight into production methods and problems in iron and steel making and shaping, some characteristic problems in research, and the way in which a steel company is staffed and administered. During their stay, the members of the Conference visited a number of United Steel establishments—Appleby-Frodingham Steel Company, Samuel Fox and Co. Ltd., Steel, Peech and Tozer and the Central Research and Development Department—and also the Sheffield Laboratories of the British Iron and Steel Research Association.

During the preceding week, a similar course was organised for masters of Public Schools, at which were present 37 masters representing 26 of the famous schools in the country.

The Recovery of Zinc from Dross

By A. G. Thomson

Several methods have been suggested for the recovery of zinc from galvanising dross, including distillation, which is the most efficient process on a large scale, and a number of techniques more suited to operation on small quantities. Following a consideration of the basic principles, the author discusses the economic aspect of the subject.

IN the days when zinc was scarce and costly, it became urgently necessary to examine all possible methods of conserving available supplies. One of the most promising fields for investigation was the recovery of the metal from galvanising dross, to which considerable attention has been devoted since the war.

Zinc dross is produced in the galvanising pot by the interaction of zinc with iron from the container, the rig and the steel sheets: it contains 94% zinc and 6% iron. Being heavier than zinc it sinks to the bottom of the pot and is periodically removed by means of a perforated ladle or scoop. When the dross is removed by this rather crude method it contains some entrapped zinc, which is usually recovered by liquation.

The iron in dross is derived from three sources, namely: (1) pickle salts not removed in the rinsing process; (2) iron salts formed by the action of the flux on the article to be galvanised; and (3) direct attack by the molten zinc on the article galvanised, the pot and any other source of iron. Dross formation can therefore be controlled by reducing the iron introduced from the first two sources, and operating the galvanising bath in such a manner that the third source is minimised. Avoidance of bath overheating by good temperature control is the chief factor in efficient operation.

Statistics show that dross formation in the general galvanising industry varies widely. As might be expected, it is lowest in plants galvanising relatively simple shapes in large quantities, especially when the material treated has a smooth surface. Efficient operation under favourable conditions would result in the conversion of about 10% of the zinc purchased into dross. This result would also be approximately correct for sheet galvanising. At the other extreme, the galvanising of miscellaneous articles, including castings, may result in over 30% of the zinc used being converted into dross.

The handling problems involved in dross removal bear no relation to these figures. Sheet- and tube-galvanising units have comparatively low figures for dross formation per ton of zinc used, but the tonnage galvanised and the weight of zinc consumed are usually much greater than in general galvanising of miscellaneous articles. The amount of dross formed by a single sheet galvanising unit may thus amount to two or three tons a week.

It is evident that during periods of shortage an efficient process for recovering zinc from dross can result in a very substantial addition to available supplies. Various methods have been developed, the objective being either to recover as much as possible of the entangled bath metal (the residual dross being sold), or to recover both the entangled metal and the zinc which is combined with iron in the dross.

Partial recovery may be effected either by liquation or by a settling process. In the former method the

material is treated on a sloping hearth, which is kept at such a temperature that one component melts and runs away, while the other remains unaffected. A process of this type is not suitable for reclaiming zinc for galvanising purposes, since the melted zinc carries with it fine dross crystals and is itself oxidised in the process. In the second method, settling of the dross may be used to recover 25-30% of the weight of the dross as zinc of usable quality, provided that overheating has not occurred, but careless operation of this process may lead to a high iron content in the zinc. Various modifications of both the liquation and settling processes have been proposed.

The "Aluminium" Recovery Process

Methods for the "complete" recovery of zinc are based either on distillation or on the so-called "aluminium" process. The most direct method of recovery is to distil off the zinc from a retort and condense it again in a suitable receiver. This process requires rather specialised equipment and is conducted at a high temperature, a further disadvantage being that skilled supervision is required. The recovery is high, but the process is not economic unless it is used on a fairly large scale. A plant of this type, operated by a large American company, is treating 200 tons of dross a month with an average yield of 88% of the weight of dross charged. This firm claims to have produced zinc slightly below market price, even at pre-1939 levels. On the other hand, the management of a German tube and galvanising works using a distillation plant of a slightly different design considered that the process was economic only at high zinc prices (about £125 per ton) or, alternatively, at low dross prices.

When galvanising is carried out with appreciable amounts of aluminium in the molten zinc, the dross formed contains sufficient aluminium to cause it to float. Proposed methods for the recovery of zinc by adding aluminium to the bath are based on the following three facts:—

(1) Aluminium has a greater affinity for iron than has zinc.

(2) The compound of iron and aluminium formed requires only $1\frac{1}{2}$ parts of aluminium to 1 part of iron, compared with $15\frac{1}{2}$ parts of zinc in the alloy *zeta*. Therefore, with dross containing 4% iron, the addition of 6 lb. of aluminium liberates 96 lb. of zinc.

(3) The alloy formed is much lighter than molten zinc and has a high melting point ($1,150^{\circ}\text{C}.$). The upward separation is faster than the sinking of ordinary dross, due to the greater difference in density, and removal by skimming from the surface is easier and more efficient than scooping from the bottom of a bath. Though processes based on these principles have been described, they have never been operated successfully on

a commercial scale. Yields have been too low, the recovered zinc has been too high in aluminium, and the separated iron-aluminium compound containing much unrecovered zinc has been unsaleable. The recent change in the relative prices of zinc and aluminium has also been unfavourable to this method.

Modified Process Using Lead

A modified process for reclaiming zinc from galvanising dross is the subject of a recent patent application by the British Iron and Steel Research Association. The proposed method is based on the facts that aluminium has a greater affinity for iron than has zinc and that the solubility of zinc in lead is only 2% at the freezing point of zinc (418° C.) but is 14% at 720° C.

Sufficient aluminium is added to molten dross to combine with all the iron present and the mixture of dross and aluminium is heated in a bath of lead to a temperature of 700° C. or slightly above. The increased difference in density between the iron-aluminium alloy and the lead-zinc alloy makes it easy to remove the former, and the remaining solution of zinc in lead is cooled until the zinc solidifies, when it can be removed.

Crucible trials of the lead-bath method using about 2 lb. of dross gave satisfactory recoveries and were followed by three works trials, using approximately 1-cwt. batches of dross which had already been treated for zinc recovery and contained 4% iron. It was found that 85% of the zinc could be recovered, the iron content being negligible. Further trials have been arranged to improve the method of removing the aluminium-iron layer without contamination with the lead-zinc.

Financial Considerations

The financial results of any recovery process are clearly dependent on the relative prices of zinc and dross, the efficiency of recovery, and the operating costs of the process employed. For example, when dross is £40 a ton and zinc £60, a recovery process yielding 90% would be profitable only if the operating cost was less than £14 per ton, but with zinc at £80 and dross at £40, recovery would cease to be economic only when the cost reached £32.

During the pre-war period 1926-39, the price of dross varied between 83 and 100% of the price of zinc. In those days zinc ranged in price between £12 and £37 a ton; hence the financial loss from dross formation was never greater than £3 11s. 6d. per ton of dross produced, allowing for the fact that dross contains 97% zinc. It follows that a "total recovery" process, even if it recovered *all* the zinc in the dross, would not have been economic unless operating costs were below the very low figure of £3 11s. 6d. per ton. Partial recovery merely reduces the financial loss resulting from dross formation. For example, if 25% by weight of good zinc is recovered and the dross is sold without penalty due to the increased iron, the loss is reduced by a quarter.

Since the outbreak of war in September, 1939, the prices of zinc and dross have both been subject to very wide fluctuations. From 1946 to November, 1952, there was usually a sufficient disparity between the price of dross and the value of the zinc contained therein to make any recovery process worth while which had operating costs less than £10 per ton of dross treated, and which obtained 90% of the weight of the dross as usable zinc. Throughout almost the whole of 1949 it would have been economical to recover 90% of the zinc at a cost of £20

per ton of dross treated. At average 1949 prices a recovery process transforming 1 ton of dross into 0.90 ton of usable zinc would save £24 ls. 0d. per ton of dross treated. Based on a production of 975 tons of dross in 1949 (an under-estimate), the net profit to the country would be £22,246 per month or £266,950 for the whole year, less the recovery costs.

Throughout almost the whole of 1951, the value of the 90% recovered zinc would have been equal to the price obtainable for the dross. On the other hand, during the second half of 1952 the price ratio of dross to zinc was exceptionally low. From June to November, the recovery of 90% zinc from a ton of dross would have meant a profit of £55.

A key factor in the world smelter production of zinc is that only six out of some twenty producing countries normally have an available export surplus. These six countries usually export around 500,000 tons (say 20% of world production) and it is this amount only which actually constitutes the international slab zinc market. This must tend to accentuate price movements each time consumption fluctuates and stocking policy veers with the economic outlook.

The fluctuations in the economics of zinc recovery call for a simple process with a small capital outlay and low working costs, which can be operated intermittently by relatively unskilled labour diverted from other work.

Because of its nature the distillation process is unsuitable for small-scale and intermittent operation by galvanisers lacking in technical skill, though recovery by this method would give the best results where large quantities of dross are treated under scientifically controlled conditions. In its simplest form, the aluminium method meets the requirements of low capital costs and low operating costs, but, as previously stated, it has not been successful.

The process developed by B.I.S.R.A. is a simple one, requiring less skill than galvanising itself. Though costs are increased by the use of lead, it offers important advantages. For instance, the zinc is removed as a block, solidified within a frame almost as big as the bath itself, which may, if desired, be immediately transferred to a galvanising bath and melted off. Another useful feature is that by eliminating the ladling out of a liquid layer of zinc, labour is reduced and the simultaneous ladling of some of the lead bath is avoided.

The proposed lead/aluminium process appears to be a promising method of zinc recovery. Tests on a fully industrial scale have not yet been carried out, but it is estimated that the costs should not exceed £10 per ton of dross treated. On this basis, the method merits consideration, not merely as an insurance against future scarcity of zinc, but also as a means of providing valuable savings whenever the margin between the prices of zinc and dross is sufficiently wide.

Birlec Joins A.E.I.

THE Mond Nickel Co. Ltd., on behalf of its parent company The International Nickel Company of Canada, Ltd., announces that following negotiations between Associated Electrical Industries, Ltd., Mond and Birlec Ltd., the sale by Mond of its wholly-owned subsidiary Birlec to A.E.I. has been agreed. Birlec will operate as an individual company within the A.E.I. Group, and Mr. G. P. Tinker will continue as Managing Director and Mr. T. G. Tanner and Mr. J. H. Crossley as Executive Directors.

An Estimation of Some Unknown Surface Tensions for Metals

By J. W. Taylor, Ph.D., B.Sc., A.R.T.C.

Atomic Energy Research Establishment, Harwell

The surface tensions of twenty-seven metals have been estimated in cases where experimental data is lacking. Five correlations have been employed. Two of these, employing the relationship between the surface tension of a metal and its heat of vaporisation, yield surface tension values which are considered accurate to better than $\pm 10\%$. The remaining three correlations, while less exact, generally confirm the values thus deduced. The estimated values are substantiated by indirect experimental data.

THE surface tension of metals is of interest in both technological and theoretical problems. Bailey¹ has shown that the surface tension is of considerable importance in the brazing of metals, controlling as it does the spreading of the liquid phase on the solid and its penetration into the joint. In casting technology, while the surface tension of the metal does not appear to be of prime importance, its significance in relation to mould penetration has been established by Atterton and Hoar², and also by Portevin and Bastien³. Furthermore, in the comparatively new field of liquid metal coolants, the role of surface tension may be a significant one from two points of view. In the first place, the wetting of the heat exchanger tubes is controlled by factors similar to those discussed by Bailey, and in the corrosion by liquid metals the surface tension of the metal may be a significant factor in the corrosion process, affecting as it does the interfacial tension between the liquid and the solid phase. Finally, in the study of cermets a knowledge of the surface tension of the metal is essential to an understanding of the bonding process, as stressed in a recent paper by Williams and Murray⁴.

Academically, the surface tension of metals is of some interest. Thus, in a study of the structure of the liquid metal state, a knowledge of the surface tensions of metals may assist in elucidating the molecular form present, and Pelzel⁵ has carried out an approximate analysis of the surface tension properties of the systems Sn/Zn, Mg/Zn, Al/Mg, and Al/Zn. In processes of nucleation and growth in the liquid state, the surface tension of metals affects the interfacial tension between the solid and liquid phases and, thereby, the size of the stable nuclei. Finally, the verification of several physico-mathematical calculations of surface energies for metals depends upon the existence of accurate practical data.

Experimental surface tension figures exist for only about 50% of all the metallic elements, excluding the rare-earth group, and a practical determination of this property for many of the remaining metals would prove difficult experimentally, owing to their chemical reactivity, their refractoriness, or their scarcity. Furthermore, it would appear that the several physico-mathematical calculations which have been made of the surface energies of metals can do little more than indicate an order of magnitude, and this only for the comparatively simpler metals where the Sommerfeld free-electron model of metallic structures is applicable with some accuracy. This is probably best seen from Table I where

TABLE I.—A COMPARISON OF THE CALCULATED AND EXPERIMENTAL SURFACE TENSION VALUES FOR METALS.

Metal	Surface Tension at the Melting Point (ergs/sq. cm.)	
	Calculated	Experimental
Cu	740	1,220
Au	450	1,128
Ag	450	923
Li	400	—
Na	190	190
K	70	86
Rb	50	—
Cs	40	—
Hg	390	465

the surface tension values of a number of metals are compared with those calculated by Stratton⁶; his treatment is the most physically-accurate wave-mechanical analysis of surface energies so far considered.

A number of reasonably accurate correlations appear to exist, however, between the surface tensions of liquid metals and other physical properties of the elements, and it seemed possible that the surface tensions of a number of metals, for which experimental data was lacking, might be predicted with some degree of accuracy from these correlations.

It is proposed to present these correlations, to discuss on what theoretical grounds they are justifiable, and, finally, to estimate the surface tensions of metals not so far studied experimentally.

Physical Correlations Employed

(i) Relationship between the Total Surface Energy and the Atomic Volume.

Smith⁷ first established a relationship between the surface tension of liquid metals and their atomic volumes, and similar relationships have subsequently been discussed by Atterton and Hoar², and by Leadbeater⁸.

A log-log plot of the total surface energy against the atomic volume is shown in Fig. 1 for metals whose surface tensions have been measured. The total surface energy σ_T is given by the equation:—

$$\sigma_T = \left(\sigma - T \frac{d\sigma}{dT} \right) \text{ ergs/sq. cm.} \quad (1)$$

where σ_T = total surface energy
 σ = specific surface tension at $T^\circ \text{K}$.
 $\frac{d\sigma}{dT}$ = temperature coefficient of surface tension

The atomic volume V is expressed thus:—

$$V = \frac{A}{\rho} \text{ cu. cm.} \quad (2)$$

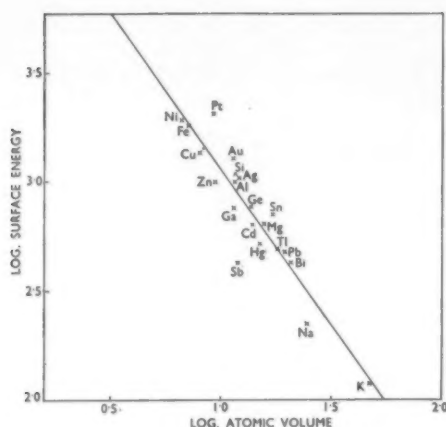


Fig. 1

where A = atomic weight of the element
 ρ = density of the element at $T^\circ \text{K}$.

Fig. 1 indicates a relationship of the form :-

$$\sigma_T \propto \left(\frac{A}{\rho}\right)^{-1.41} \quad (3)$$

The existence of such a correlation is by no means unexpected on theoretical grounds. Thus, an early electronic theory of the surface tension of metals by Gogate and Kothari⁹ considers the energy of free electrons confined to a two dimensional thin film, representing the metal surface, and hence derives an expression for the surface tensions of metals of a form :-

$$\sigma_T \propto \left(\frac{A}{\rho}\right)^{-\frac{4}{3}} \quad (4)$$

Brager and Schuchowitzky¹⁰ likewise derive an identical expression with a slightly modified proportionality constant. In the later theories of Huang and Wyllie¹¹, and of Stratton⁶, a term involving the atomic volume $V^{\frac{1}{3}}$ appears in the denominator of the final expression for the surface energies of the metals. In these later treatments, however, the relationship is not a simple proportional one, suitable correction terms being incorporated to take into account such effects as the thermal vibration of the lattice, the electrostatic energy of the

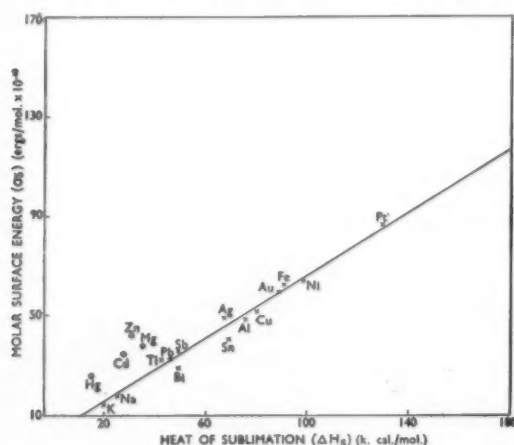


Fig. 2

TABLE II.
VALUES OF PHYSICAL PROPERTIES EMPLOYED

Element	Atomic Volume at Melting Point (cu. cm.)	ΔH_s (k. cal./mol.)	Molar Surface Area $[fN^{\frac{1}{3}}(\frac{A}{\rho})^{\frac{2}{3}}]$ (sq. cm. $\times 10^{-8}$)	Melting Point ($^\circ \text{K}$)	Density at 20°C . (g./cu. cm.)	Elastic Modulus (kg./sq. mm.)
Ba	38.45	46.0	10.59	977	3.75	500
Be	5.78	80.0	2.99	1,556	1.82	13,500
Cs	77.39	18.8	16.87	302	1.87	—
Ca	27.77	45.4	8.52	1,123	1.55	750
Ce	21.26	53.0*	7.13	1,048	6.9	—
Cr	8.16	93.5	3.77	2,173	7.1	7,300
Co	7.63	105.0	3.60	1,723	8.71	7,630
Cb	12.14	175.6	4.91	2,760	8.4	6,000
Hf	17.21	170.0	6.19	2,500	11.4	3,100
In	15.98	59.1	5.89	430	7.3	380
Ir	9.48	165.0	4.16	2,716	22.4	21,400
Li	13.64	37.96	5.30	453	0.53	430
Mn	8.55	69.7	3.88	1,517	7.4	7,800
Mo	10.08	136.0	4.34	2,833	10.4	12,300
Os	9.46	174.0	4.16	2,973	22.5	22,800
Pd	9.92	93.0	4.29	1,823	11.9	4,450
Re	10.64	189.0	4.50	3,420	20.53	21,000
Rb	58.43	20.5	13.98	311	1.53	—
Sr	35.27	39.2	9.99	1,043	2.6	620
Ta	12.04	200.0	4.88	3,250	16.6	7,000
Te	21.39	36.7	7.16	723	6.24	—
Th	22.03	88.5*	7.30	2,113	11.5	3,160
Ti	11.64	111.7	4.77	2,085	4.5	3,870
W	10.47	202.6	4.45	3,653	19.32	15,140
U	13.66	116.6	5.31	1,409	18.7	4,600
V	9.39	120.0	4.14	2,003	5.96	5,500
Zr	15.50	142.2	5.77	2,125	6.5	3,540

* Trouton's Rule Value.

surface double layer, etc. These corrections appear to have a minor effect on the general relationship between the surface tension and the atomic volume; they probably account for the observed discrepancy in the powers appearing in practical and theoretical relationships, i.e. -1.41 and -1.33 respectively.

(ii) Relationship between the Total Molar Surface Energy and the Heat of Sublimation.

Leadbeater⁸, has indicated a general relationship between the surface tension of liquid metals and the cohesive properties of the solid metals, as represented by their melting temperatures, heats of sublimation, etc. In fact a plot of total molar surface energy σ_0 against the heat of sublimation of the solid metal ΔH_s , Fig. 2, indicates that a simple proportional relationship is approximately true for many metals. The total molar surface energy σ_0 is represented thus :-

$$\sigma_0 = fN^{\frac{1}{3}}\left(\frac{A}{\rho}\right)^{\frac{2}{3}}\left(\sigma - T\frac{d\sigma}{dT}\right) \quad (5)$$

where f = packing fraction for atoms in the surface.*

N = Avogadro's number

A = atomic weight of the element

ρ = density of the element

σ = specific surface tension at $T^\circ \text{K}$.

$\frac{d\sigma}{dT}$ = temperature coefficient of surface tension

The points for Hg, Cd, Zn, and Mg, differentiated from the other metals in Fig. 2, were not included in the final linear relationship as they appeared to lie well above the latter. It is not clear whether this is a true effect reflecting an anomalous behaviour of hexagonal metals, or whether the discrepancy is accountable on the basis of experimental errors. It may be relevant in this connection that the metals Hg, Zn, and Mg show a similar behaviour in the following correlation, where their excess binding energy ϕ is negative compared with the positive values shown by all other metals.

* For close packed structures, $f = 1.09$, and for body centred cubic ones, $f = 1.13$.

TABLE III.—ESTIMATED SURFACE TENSIONS OF METALS AT THEIR MELTING TEMPERATURES.

Correlation	(i)	(ii)	(iii)	(iv)	(v)
Figure No.	1	2	3	4	5
Metal	Surface Tension at the Melting Temperature (ergs/sq. cm.)				
Ba	70	190	200	430	390
Be	2330	1610	1630	1910	1800
Ca	30	50	60	190	—
Co	160	250	260	560	400
Cr	290	390*	400*	610	—
Cu	1310	1410	1430	2060	1620
Fe	1310	1740	1680	1740	1750
Mo	600	2050	2050	2000	1480
Ni	280	1540	1540	1450	1080
Pt	550	620	640	360	360
Sn	1000	2310	2310	2300	4400
Tl	700	470	420	400	410
Zn	1280	1040	1060	1440	1710
Al	850	2060	2060	2340	2490
Ag	950	2420	2420	2520	4610
Pb	960	1240	1260	1540	1330
Bi	710	2390	2390	2650	4250
Rb	60	70	80	200	—
Sr	90	160	170	470	400
Ta	560	2340	2330	2330	1900
Te	320	280	290	460	—
Th	170	590*	590*	1080	1070
Ti	720	1320	1330	1580	1000
W	710	2590	2590	2860	3330
U	600	1030	1030	1000	1490
V	1060	1690	1700	1750	1310
Zr	410	1390	1400	1340	1020

* ΔH_s Value from Trouton's Rule.

Skapski's¹² physico-chemical treatment of the surface tension of metals indicates that such a correlation has some justification theoretically. Thus, on the hypothesis that the molar surface energy of a liquid may be regarded as the difference in the potential energy of atoms in the bulk of the liquid and on the surface, an expression is derived for the molar surface energy σ_0 in terms of the heat of sublimation thus:—

$$\sigma_0 = \left(\frac{Z_i - Z_a}{Z_i} \right) \Delta H_s \quad (6)$$

where Z_i = co-ordination number of an atom in the bulk of the liquid

Z_a = co-ordination number of an atom at the surface of the liquid

On this basis, the observed correlation, Fig. 2, has considerable theoretical justification.

(iii) Relationship between the Excess Surface Binding Energy and the Heat of Sublimation.

Oriani¹³ has criticised Skapski's treatment of the surface tension of metals on the grounds of his assumption of equal pair-wise bonding of atoms in the bulk of the liquid and on the surface. Oriani postulates that, in fact, these bond energies are different, and he calculates this difference from essentially similar considerations to those employed by Skapski, except that he applies a more exact analysis to the packing in the liquid surface layer. Thus he finds that the excess surface binding energy ϕ is given thus:—

$$\phi = \frac{2}{Z_a} \left[\left(\frac{Z_i - Z_a}{Z_i} \right) \Delta H_s - \sigma_0 \right] \quad (7)$$

where Z_i = co-ordination number of an atom in the bulk of the liquid.

Z_a = co-ordination number of an atom in the surface of the liquid.

ΔH_s = heat of sublimation of the element.

σ_0 = total molar surface energy as given by expression (5).

It was found that ϕ was approximately proportional to the heat of sublimation and this is confirmed for a large

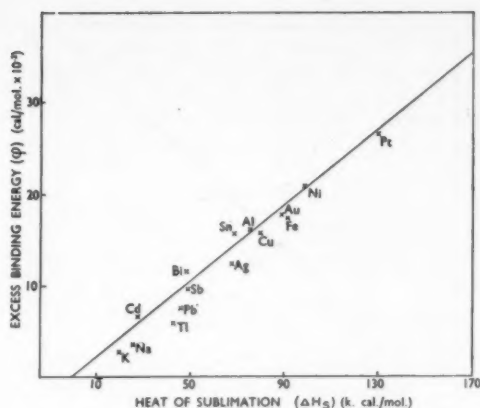


Fig. 3

number of metals as shown in Fig. 3. It is thus clear that the total molar surface energy σ_0 is a direct function of the heat of sublimation as indicated in relationship (ii) above and it was considered interesting to compare the surface tensions of some metals as estimated from these two similar relationships. This has been done in columns ii and iii of Table III.

(iv) Relationship between the Surface Tension at the Melting Temperature and the Ratio $T_{M.P.}/V^{\frac{1}{3}}$

Schyttil¹⁴, derived an expression for the surface tension of liquids in terms of their molecular weight, their refractive index, and the frequency of thermal vibrations therein and this expression when combined with the Lindemann melting point expression yields the simple relationships:—

$$\sigma_{M.P.} \propto \frac{T_{M.P.}}{V^{\frac{1}{3}}} \quad (8)$$

where $\sigma_{M.P.}$ = surface tension at the melting point

$T_{M.P.}$ = melting point in $^{\circ}\text{C}$.

V = atomic volume at the melting point

Fig. 4 indicates that this relationship is approximately true for a large number of metals, and would thus furnish an additional means of estimation of unknown surface tension values.

The relationship is essentially that incorporated in the well known Eötvös rule and this has been derived on strictly theoretical grounds by Lennard-Jones and Corner¹⁵.

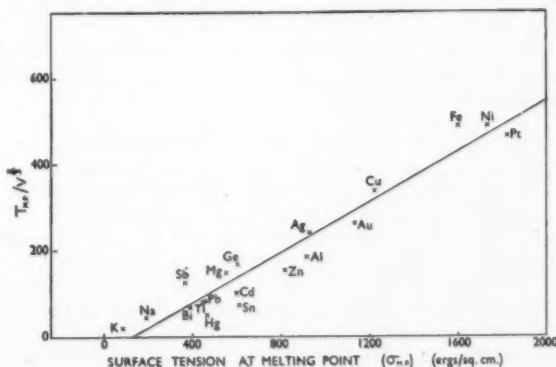


Fig. 4

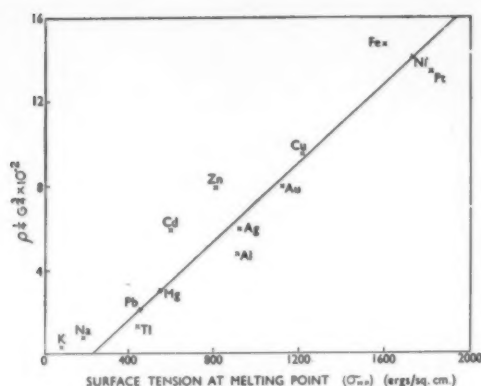


Fig. 5

(v) Relationship between the Surface Tension at the Melting Temperature and the Factor $\rho^{1/3} G^{1/2}$.

Several semi-quantitative expressions have been derived for the surface tensions of liquids in terms of the elastic properties of the solid phase. From a consideration of the interatomic forces in metals, Weng-Po¹⁶ obtained an expression for the surface tension of liquids in terms of the characteristic infra-red frequency and the atomic weight, while Auerback¹⁷ established that expression (9) was true approximately for liquids, viz.,

$$\sigma \propto \rho v^3 \quad (9)$$

where σ = surface tension of the liquid.
 ρ = density of the liquid
 v = velocity of sound in the liquid.

Expression (9) is readily stated in terms of the elastic modulus of the solids by means of expression (10), viz.,

$$v \propto \sqrt{\frac{G}{\rho}} \quad (10)$$

where G = elastic modulus

Hence :-

$$\sigma \propto \rho^{1/3} G^{1/2} \quad (11)$$

Fig. 5 indicates that this correlation is approximately true for metals whose surface tensions have been established.

It appears unlikely, in view of the approximations involved in the derivation of expression (11), that any accurate theoretical basis will be found for this relationship. Mott¹⁸ has certainly shown that the elastic modulus is related to the heat of fusion of metals, and Jollivet¹⁹ has related the latter quantity to the atomic vibrations in a metal (which in turn can be related to surface tension by an expression such as (9)), but the inter-relationship does not appear to be a perfectly quantitative one.

Values of Physical Properties Employed

The values of the appropriate physical properties of the metals of unknown surface tension, to be used in conjunction with Figs. 1-5, are listed in Table II.

Atomic volume values for the liquid metals at their melting temperatures had to be obtained indirectly, as experimental values were lacking for the majority of the metals in Table II. The method adopted for calculating this value comprised correcting the reported room temperature densities²⁰ for the expansion of the solid to the melting temperature, and then applying a fixed volume change of 0.5-1.0 cu. cm./mol. for the change

in volume on fusion. Owing to the uncertainty involved in the thermal expansion data and in the volume change on fusion, the accuracy of the atomic volume figures in Table II is not considered to be high.

The heats of sublimation are those reported either by Kubaschewski and Evans²¹, or by Quill²² except for cerium, and thorium. As experimental values did not exist for these metals, values were estimated from Trouton's rule.

Molar surface areas were calculated from the reported atomic volumes in conjunction with expression (5); a value of $f=1.10$ was used in these calculations. Melting points are taken from Kelly's data²³, while the room temperature densities are those reported by Smithells²⁰; the elastic moduli are taken from a recent compilation by Pugh²⁴.

Estimated Surface Tension Values

Surface tension values as estimated from the physical properties contained in Table II, in conjunction with Figs. 1-5, are listed in Table III, where the vertical columns have been numbered in such a way as to indicate the relationship used in deriving the value in question; figures numbers are also included.

In order to make a more exact comparison of the several figures possible, all the data are referred to the melting temperature of the metal in question, and to do this it has been necessary to use an arbitrary temperature coefficient of -0.1 ergs/sq. cm./° C. in correlations (i), (ii), and (iii) where the surface energy is first derived.

The surface tension figures derived from the atomic volume correlation (i) appear generally to be considerably lower than those from the other relationships, and this is the result of two factors. In the first place, the atomic volumes of the liquids were derived in a somewhat uncertain manner, and there is probably a considerable error in the final values. Secondly, the correlation of atomic volume and surface energy, Fig. 1, shows a considerable scatter from the linear relationship assumed, when the log/log nature of the plot is considered. Thus the accuracy of the estimated surface tensions from this correlation is undoubtedly less than that given by relationships (ii) and (iii).

These two latter give values which compare excellently. This is to be expected from the similar nature of the basic relationships, for although method (iii) involves the difference between a fraction of the heat of sublimation and the excess surface binding energy (expression 7) the latter is proportional to the heat of sublimation thus rendering the methods of estimation essentially identical. It would appear from Fig. 2, and the scatter of points therein, that the estimated surface tensions from this correlation are in error by a factor of less than

TABLE IV.—PROBABLE SURFACE TENSIONS OF METALS AT THEIR MELTING TEMPERATURES.

Metal	Surface Tension (ergs/sq. cm.)	Metal	Surface Tension (ergs/sq. cm.)
Ra	195	Os	2450
Be	1620	Pd	1280
Cs	55	Re	2480
Ca	255	Rb	75
Ce	610	Sr	165
Cr	1420	Ta	2330
Co	1740	Tc	300
Cb	2030	Th	1075
Hf	1510	Ti	1325
In	630	W	2680
Ir	2310	U	1020
Li	430	V	1710
Mn	1050	Zr	1380
Mo	2240		

10%. When it is recalled that experimental determinations of surface tensions, as measured by different workers, in themselves often differ by as much as 20%, it will be appreciated that such an error in the estimated values is by no means excessive for this particular physical property.

The estimated values from correlations (iv) and (v) show a considerable scatter round the values obtained from the two previous correlations, where the magnitude of the surface tension is less than about 500 ergs/sq. cm. Above this order of magnitude, agreement in the four cases is often quite good. The relatively inferior correlations between the surface tension and the other parameters, as shown in Figs. 4 and 5, would account for the observed disparity at low absolute surface tensions. In the case of cerium and thorium, whose heats of sublimation were estimated by Trouton's rule, it is considered that the surface tension figures as estimated by method (iv) and (v) are more probable than those given by relationships (ii) and (iii).

On the basis of these several considerations, the most probable surface tension values for those metals at their melting temperatures are summarised in Table IV.

Conclusions

The correlation between atomic volume and surface tension yields results which are considerably lower than those given by the other methods of estimation, and owing to the poor nature of this correlation the values are subject to considerable uncertainty. The two methods of estimation employing the heat of sublimation give surface tension values which are probably accurate, to better than $\pm 10\%$ except in cases where the heat of sublimation is uncertain. The two remaining correlations, in general, confirm the values obtained from the heats of sublimation, except at low absolute surface tension values, where inaccuracies in the correlation make the predicted values uncertain.

That the estimated values are of the correct order of magnitude is suggested by the following comparisons. Powers and Wilhelm²⁵ from measurements made on solidified sessile drops, give the following values for the surface tensions of some metals: titanium, 1,210 ergs/sq. cm.; vanadium, 1,510 ergs/sq. cm.; and thorium, 1,010 ergs/sq. cm. The corresponding estimated values are 1,330, 1,700, and 1,080 ergs/sq. cm. respectively. When it is considered that those experimental values are subject to the errors involved as a result of solidification shrinkage of the drop, the estimated values can be seen to be in agreement with probable true experimental values. (For nickel, the value given from the measurements on a solidified drop is 1,200 ergs/sq. cm., whereas the true experimental value is 1,735 ergs/sq. cm., a difference of some 30%). Kingery *et alia*²⁶ on the basis of the assumptions (a) that the surface energy is due to unsaturated chemical bonds at the surface; (b) that the number of surface bonds can be calculated; and (c) that the molar heat content of the bonds can be calculated from the heat of vaporisation; have given the following calculated values in ergs/sq. cm. at the respective melting points: beryllium, 1,960; titanium, 1,460; zirconium, 1,500; and molybdenum, 2,600; the corresponding estimated values are 1,620, 1,330, 1,400, and 2,060 ergs/sq. cm. Finally, in a recent paper Zadumkin²⁸, from a consideration of the co-ordination numbers of atoms at the surface and in the bulk of the liquid, has calculated the following surface tension

values, in ergs/sq. cm.: strontium, 220; cobalt, 1,770; calcium, 342; lithium, 473; caesium, 78; rubidium, 100; tantalum, 1,600; molybdenum, 2,390; columbium, 1,120; tungsten, 3,160; zirconium, 2,210; hafnium, 1,490; osmium, 3,520; rhodium, 5,450. These can be compared with the corresponding estimated values set out in Table IV.

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Correction

BONDING IN CERMETS

We regret that the following errors appeared in the paper on "Bonding in Cermets," which was published in the May issue of *METALLURGIA*.

Page 210. The fifth line from the bottom of the first column should read . . . siderations. As with metal alloys, the properties of the . . .

Page 212. In Table I the complete right hand sides of equations II, III and IV should be bracketed before multiplying by 10^6 .

Page 216. In the ninth line of the second column, the word "quality" should read "quantity."

Straightening Press Order

THE Head Wrightson Machine Co. Ltd., of Middlesbrough, have recently received an order from Dorman, Long and Co. Ltd. for four large straightening presses which are valued at over £400,000. These presses will be installed in the combined universal beam and heavy section mill which is to be erected at the Lakenby Works, and will be used for the straightening of the very heavy universal beams to be produced in that mill. Each of these machines will weigh over 300 tons and will probably be the largest units of their kind ever built in this country.

It is fitting that this important contract should have been placed on Tees-side with the Head Wrightson Machine Co. Ltd. whose facilities for the production of heavy machinery are well known throughout the iron and steel industry at home and overseas. This contract will provide an appreciable load for their heavy machine and fitting shops and, in addition, a large number of steel castings will be supplied by the Steel Foundry Division of the parent company Head, Wrightson and Co. Ltd., of Thornaby-on-Tees.

Standardisation in Furnace Design

New Multi-Purpose Types

THE wide field of application of the batch type of heat treatment furnace, with its adaptability for handling materials ranging considerably in size and quantity, and in treatment required, has conflicted with the development of really standardised types which can be produced other than by one-off methods. It has, however, been possible to evolve certain types conforming to a basic design which can be repeated for a wide variety of applications, and Birlec, Ltd., have decided to combine the separate features of two of theirs, the RP and SA types, into a new standard type of equipment to be known as the RS type. The RP was developed for annealing, normalising, hardening, tempering, nitriding, pack carburising and other processes up to about 1,050° C., and was the first furnace of its kind to have additional heating elements on the inner face of the door. The SA is similar in construction but it incorporates the "Certain Curtain" system of atmosphere control.

In designing the new RS type, the makers have shown their awareness of the modern trend towards clean, uninterrupted external surfaces and the casing of this new unit, which has been given a sloping front and rounded corners, is a pleasing departure from the "rawboned" angularity of earlier designs. Also conforming to modern machine shop standards is the more attractive paintwork finish which is being given to this new furnace as a change from the conventional aluminium or dull grey colouring of most heat-treatment plants. The door-operating gear with its counterbalance weights is now housed within the furnace casing, which also encloses the transformers, contactor panel and ancillary equipment. Access to these is gained through quickly detachable panels. The door lifts vertically and is self-clamping against the sloping front of the furnace vestibule, this arrangement providing a very efficient seal against heat and atmosphere losses. A lever at the side of the furnace is used to raise and lower the door.



General view of the furnace with its sloping front and rounded corners.

Hearth Design

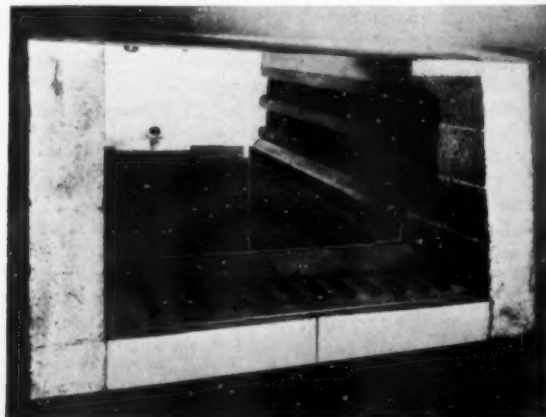
One of the most important improvements is in the hearth design. Instead of a single metal plate, this now consists of a number of small interlocking plates which "dovetail" together to form a single unit, or a divided plate. As provision is made for expansion at the interlocking joints, buckling of the hearth plate through heat distortion is practically eliminated.

One furnace is nominally rated at 30 kW. from a standard 3-phase electricity supply and heating is achieved by means of special very heavy section tape elements manufactured from a nickel-chromium heat-resisting alloy. The heating elements are arranged in the furnace roof, side walls and beneath the furnace hearth plate so that maximum temperature uniformity is obtained, and are mounted in slotted bricks so that individual elements can be withdrawn quite easily and quickly from the furnace without disturbing any brickwork, a factor which can offer considerable economies in shutdown time during maintenance operations.

All the necessary automatic temperature control equipment is provided with the furnace, the control instrument being of the indicating type, and operating in conjunction with a triple-pole magnetic contactor unit. It is mounted in a steel panel which is built on to the side of the furnace casing, while the remainder of the furnace electrical equipment, such as switchgear and transformer, is mounted beneath the furnace.

Atmosphere Control

A special atmosphere control system with the necessary valves, inter-connecting pipework and burners is built into the furnace, town's gas and air being fed into a small combustion chamber located below the furnace vestibule. A removable plug at the side of the furnace gives access to the combustion chamber so that periodically this may be cleaned out without disturbing the main brickwork. For applications where a controlled



The hearth consists of a number of small interlocking plates to reduce distortion.

atmosphere is not required, and to make it suitable for the class of work for which the RP furnace is generally used, the RS model is supplied with an additional heating element on the door and without the "Certain Curtain" arrangement.

As already indicated, the size and rating of this new RS model should meet the requirements of a large body of users, but for those dealing with smaller types of components and lower outputs, a unit of 20 kW. nominal rating is also being introduced. This will conform to the same general specifications as that of the 30 kW. unit

but, as the hearth will be of smaller dimensions and, therefore, much less liable to distortion, the jointed hearth plate will not be incorporated. In this furnace the hearth-plate will consist of two single plates loosely butted together.

As the forerunners of a new trend in standardised heat treatment equipment it is expected that these new RS models will be supplemented by further additions to the range. These are being designed with particular attention to the requirements of forges, foundries and other heavy duty users.

Sodium Hydride Descaling Plant Now Available for Contracting Work

A COMPARATIVELY new process for descaling metals, which avoids many disadvantages of conventional pickling and other methods, involves the use of sodium hydride, and is applicable to all metals except those with low melting points, and those—such as zinc and tin and their alloys—which are readily attacked by caustic soda. Not only does the sodium hydride process readily remove hot-working and heat-treatment scale from most ferrous and non-ferrous metals, but it completely rids wire of soap and similar drawing lubricants, leaving it suitable for bright annealing without risk of staining. Moreover, iron, steel, bronze and aluminium castings are entirely cleared of the last traces of residual foundry sand, even in the most intricate internal cavities, which are difficult to reach by any other means.

Sodium hydride is a very powerful reducing reagent, and when present to the extent of about 2% in a bath of molten caustic soda, it reacts with oxides present on metal in the form of scale and reduces them to a finely divided metal powder, or, sometimes, to a loosely adhering flaky foil. There is one exception to this general statement—chromium oxide is reduced to the lower oxide, but this, too, adheres loosely, and can easily be removed. After removal from the molten bath, the charge is allowed to drain for a minute or two, prior to quenching in cold water, followed by washing in a high-pressure water jet. A final swill in hot water assists the cleaning and promotes rapid drying. In some cases, particularly where a bright finish is required, a final flash pickle and wash may be incorporated in the process.

Unlike acid pickling, the sodium hydride process attacks the scale but not the underlying metal, which means that the metal cannot be overpickled, and results in appreciable savings when processing expensive alloys. The reservation has already been made that tin and zinc and their alloys, which are readily attacked by caustic soda, cannot be treated by the process, but aluminium can. Attack on this metal and its alloys is negligible, although some light etching takes place in the quenching bath which becomes, in effect, a weak solution of caustic soda.

The bath operates very rapidly, and, the reagent being very fluid, it penetrates into minute interstices, so that coils of wire rod can be descaled effectively without removing their binding wires. The same bath can be used to descale all metals to which the process is applic-

able, and hydrogen embrittlement of those susceptible to this phenomenon is impossible, the tendency being to drive off any hydrogen present in the metal.

Other advantages of the process include the absence of corrosive fumes to damage the fabric of the building or endanger the health of the operators. Furthermore, as the reagent is alkaline, and readily soluble in water, disposal of this waste is easy, and does not present the serious problems associated with acids.

Applicability of the Process

The process is not universal in application. Its unsuitability for metals which are attacked by caustic soda has already been referred to, and there is a further drawback resulting from the temperature of operation of the bath, which is in the region of 350° C. It obviously precludes those materials whose properties are gained by heat-treatment operations at lower temperatures, such as the precipitation-hardened aluminium alloys and beryllium copper.

Despite these exceptions, the process has a wide field of application. It is covered by British patents, but Imperial Chemical Industries, Ltd., will issue free licences to work it provided that the plants have been approved by them. Some 40-50 plants are now in operation in this country, mainly in the larger concerns where there is a steady demand. The installation of plant for carrying out such a process involves a fair amount of capital expenditure, and its running carries with it a fairly high continual overhead rating. Against this the actual cost of operation, while work is being processed, is attractively low—a very small labour force and expenditure on material being required to treat effectively large quantities of material in a very short period of time. It is clear, therefore, that the process requires a steady flow of work for treatment in order to realise its greatest economic potential. It is for this reason that most of the plants at present in operation are to be found in the larger industrial organisations, where a continuous throughput of work is virtually guaranteed. At the same time, there exists in all parts of the country a large number of medium-sized and small engineering and manufacturing works where the advantages offered by the sodium hydride process would be realised, were it not for the fact that the quantities of materials involved in each separate case are so small as to render the use of this method uneconomical.

A Jobbing Plant

To meet the needs of these smaller organisations, Durnall & Hipwell, Ltd. have installed at their works at Staines, Middlesex, the first sodium hydride descaling plant to be operated solely as a contracting service for the engineering industry and allied trades. The company commenced trading early last year, the intention being to provide a comprehensive range of metal pre-treatment services to be made available to all concerned with the handling of metals on a contracting basis. This section of the Company's activities—which includes facilities for descaling, derusting, degreasing and de-painting, as well as for chemical blacking of steel components—continues in the original premises, a converted boathouse.

By January of this year, the sodium hydride plant was installed in new premises built to house it. The installation, which can deal with a ton of material of average mass in one hour, comprises a number of units capable of handling work which may be contained in vats 6 ft. long \times 4 ft. wide \times 4 ft. deep. First in the line is a top-charged gas-fired preheating furnace in which the temperature of the material to be treated is raised to a value approximately that of the sodium hydride bath. This ensures that the work is perfectly dry, and that the temperature of the hydride bath is not lowered appreciably by its immersion.

The metal, which may be suspended from hooks, slung from a chain, or placed in a basket of strong wire mesh—according to its nature—is then immersed in the sodium hydride bath for a pre-determined time. The bath is an electric-arc welded mild steel tank, heated by gas and suitably insulated against heat losses. The sodium hydride is not supplied as such, but is generated in the plant by a reaction between hydrogen—in the form of cracked ammonia—and sodium. Each sodium hydride generator consists of a welded mild steel box, open at the bottom, with a hole at the top large enough to admit blocks of sodium, and covered by a lid. The box is immersed in the bath for a depth of 12–15 in., projecting about 5–6 in. above it. Two mild steel tubes pass through the top of the generator, and are carried about 9 in. below the liquid level. These serve to introduce the cracked ammonia, which bubbles up through the caustic soda to meet the layer of molten sodium floating on the surface inside the generator. The cracked ammonia is piped from I.C.I. ammonia crackers fed from cylinders of anhydrous ammonia. Sodium, in the form of dry blocks, is fed into the hydride generators at intervals determined by the size of the plant and the amount of work passing through it. The concentration of the bath is maintained at about 2% while the plant is in operation, and a simple method of checking this value has been devised. A small amount of sludge accumulates when the plant is in operation, but this is readily removed by means of a sludge tray, made of mild steel plate and perforated with $\frac{1}{4}$ in. diameter holes, which is kept in the bottom of the tank and occasionally lifted out and cleaned.

After remaining in the bath for the requisite period, the work is taken out, allowed to drain, and quenched in cold water. The steam generated by this operation removes much of the reduced scale from the surface of the metal. This process is further assisted by washing by means of a high-pressure water jet. This may be followed by a flash pickle, particularly where a bright finish is desired. For ordinary steels and cast irons

sulphuric acid is used; for light alloys, nitric acid; for the Nimonic, ferric chloride and nitric acid; and for stainless steels and titanium, nitric and hydrofluoric acids. Incidentally, it is claimed that the sodium hydride process is the only effective method of descaling titanium.

Typical Applications

At the present time the plant is being used for the descaling and derusting of such varied items as heat-treated titanium sections; stainless steel dental instruments; copper wire and tubing; Nimonic pressings and fabrications; and forgings, heat-treated parts and fabricated parts after welding or brazing. A wide range of castings, both ferrous and non-ferrous are also being sent in for desanding. The response to this service, which the Company has now been giving for nine months, has been encouraging to a marked degree. To a large extent the scepticism and the reluctance to try something new, especially in view of the claims made for advantages over other methods, has been overcome, and the quantities of material for treatment are increasing in number and variety.

Largest Steelworks Locomotive

By a substantial margin the most powerful built in Britain for a British steelworks is a 50-ton six-wheel diesel-mechanical locomotive of 500 b.h.p. recently delivered by the Hunslet Engine Co., Ltd., to the Shotton steelworks of John Summers & Sons, Ltd., where it is now engaged in the heaviest steelwork duties. The 4 ft. wheels are spread over a wheelbase of only 9 ft., and the locomotive can go round curves of 120 ft. radius; length over buffer beams is 26 ft. A Paxman 12-cylinder V-engine of type RPH-II is installed and drives through a Hunslet friction main clutch and Hunslet six-speed gearbox. Top tractive effort in first gear ($4\frac{1}{2}$ m.p.h.) is 35,000 lb. Maximum axle load is 17 tons carrying full supplies, including 500 gallons of fuel.

Callender-Hamilton Bridges for Norway

DESPITE keen continental competition, British Insulated Callender's Construction Co., Ltd., have obtained from the Norwegian State Railways an order for three Callender-Hamilton railway bridges of 190-ft. span. A feature of the order is that hot dip galvanising of all steelwork—a process which has been used with great success on Callender-Hamilton road bridges—is to be applied to their railway bridges for the first time, and its use is expected to cut maintenance costs to a very low figure. The bridges are to be of the same standard construction as those in use in Holland since 1946 when many spans of up to 286 ft. in length were ordered by the Netherlands State Railways for reinstatement of main line crossings of waterways.

The Callender-Hamilton railway bridge is of the unit-construction type and although originally designed for emergency use in India, is coming into use, more and more, as a permanent structure. One of its advantages is that it allows spans of any length to be constructed from a number of standard sections, and the order for Norway includes the supply of additional sections to provide for any variation of span length that may be required. Fabrication and galvanising of the steelwork is being carried out by Tees Side Bridge and Engineering Works, Ltd., Middlesbrough.

CO-OPERATIVE RESEARCH ACTIVITIES

In an introduction to a report, recently published by the Organisation for European Economic Co-operation, on applied research in Europe, the following statement appears—"It has taken two world wars to demonstrate finally and conclusively that applied research and development are indispensable to continued economic solvency and to the maintenance of reasonable standards of life. The requirements of war provided the funds and material necessary for victory and survival. While now, in times of peace, the cost of defence weighs heavily on all economies, all countries of the civilised world are well aware of the continuing urgency for applying research and developing new technologies in the service of humanity (in the conquest for disease, hunger, etc.) and in the service of nations through new products, improved processes, higher outputs and productivity, improved health and welfare, and balanced budgets."

Certainly, the post-war years have seen a considerable increase in peace-time research, and although the bulk of industrial research continues—as

inevitably it must—to be carried out in the laboratories of individual firms, there has been a corresponding increase in the volume of work emanating from research associations set up to function on behalf of a particular industry or group of industries. There are now more than forty of these associations in the United Kingdom, with a total income of over £3 million—a seven-fold increase over the 1939 figure—of which the Government, through the Department of Scientific and Industrial Research, contributes rather less than half.

The work of these associations is complementary to that of the individual firms, and includes fundamental research on raw materials and processes, and applied research on urgent technical problems of general concern to the industry. Not the least important function of the associations in the struggle for increased industrial efficiency is the development of research results to the semi-scale or pilot plant stage. These and other important aspects of the work of a number of research associations in the metallurgical field will be referred to in the following pages

The British Welding Research Association

By K. Winterton, Ph.D., B.Sc., A.I.M., A.M.Inst.W.

Chief Ferrous Metallurgist.

In this brief article a survey has been made of the more important aspects of the work in the engineering and metallurgical sections of the British Welding Research Association during the past year, with particular emphasis on the new work which has been started during this time. Because of the expanding activities of the Association, plans are being made to transfer the metallurgical researches to the Abington station.

THE steady growth of the British Welding Research Association has led to problems of accommodation at Park Crescent. It has, therefore, been decided to transfer to the Abington station the metallurgical researches, and to erect there a new laboratory building as soon as plans now under discussion can be completed. An artist's impression of this new building as at present contemplated is shown as Fig. 1.

In spite of these long-term plans, some developments of interest are taking place in the Park Crescent laboratories. Fig. 2 shows a view of the new microscope room, in which two new microscopes have recently been installed. The first is a Reichert M.E.A. optical-bench-type metallurgical camera, with polarising, phase contrast and micro-hardness testing ancillary equipment; the second acquisition is a Reichert Zetopan binocular universal microscope. In addition, two rooms have been equipped by a laboratory furnisher as general research laboratories to meet the needs of the steel and light-alloy investigations respectively. A view is shown in Fig. 3 of part of the new laboratory set aside for work on light alloys.

Present figures for membership of the Association are

282 ordinary members and 30 associate members, comparative figures for the same time last year being 260 and 27 respectively. The usefulness of the Association's advisory service is evidenced by the growing number of requests for assistance, and of visits to the laboratories by members' representatives.

Twenty-three special reports have been prepared during the year, covering a very wide range of subjects dealing with members' industrial problems. In addition to this, thirty-four confidential reports have been issued to members covering progress on the main lines of work. A similar number of papers has been published in various journals, and thirteen lectures have been given to professional and technical societies by members of the staff.

General Progress

In the matter of special equipment, the Association has been particularly fortunate. A Baldwin-Tate-Emery 200-ton universal testing machine (Fig. 4), together with a Sciaky three-phase spot welding machine (Fig. 5), have been purchased from the United States, these acquisitions having been made possible by a special grant from M.S.A. funds, obtained for the Association



Fig. 1.—Artist's impression of the proposed new metallurgical laboratory at the Abington research station.

by the Department of Scientific and Industrial Research. These machines, which could not otherwise have been obtained, are most valuable additions to the large-scale testing and general research facilities of the Association.

An account is given later in this report of the progress of some of the current investigations, but it is perhaps worth while drawing special attention to two new projects which have been commenced during the year. The first of these is on the subject of the arc welding of copper, and springs from the recent successful introduction of the nitrogen-arc welding process by the Association and by the I.C.I., Ltd., independently, and the newly-available filler-wire compositions developed by the latter organisation. The terms of reference for this committee's work, however, are wider than these innovations might suggest. The second example of new work commenced during the year concerns a co-operative investigation on the possibility of health risks from the use of basic-coated low-hydrogen electrodes for welding steel. This work has been subdivided to cover the medical, chemical and ventilation aspects of the problem. It would not be right to omit special mention of the progress of work on brittle fracture, which has continued

to flourish, and has excited considerable attention in this most important field.

During the year the Association's rights in five patents have been assigned to the National Research Development Corporation under the agreement outlined in last year's report of progress.

Special Researches

Arc Welding of Copper

At the first meeting of the committee, the initial programme of co-operative work was agreed—to examine the effect of hydrogen in the parent plate material on weldability—and it was also decided to prepare a résumé on the attitude of the industry to their various problems in the light of the newly-available materials and methods.

Metallurgical Researches

Mild Steel Weld Metal

One approach that is being made to the problem of hot cracking in mild steel weld metal consists in the determination of mechanical properties at high temperatures. The apparatus, consisting of a specially constructed furnace used in the grips of a tensile testing machine, is shown in Fig. 6, with the particular purpose of examining the effect of hydrogen at high temperatures. A furnace of simpler construction, using H.F. heating, is being used to determine the effect of very high temperature equilibria on the mechanical properties at lower temperatures, and for this purpose very rapid heating rates are necessary.

Experiments with crack-testing machines have disclosed some unexpected results caused by variation in rate of straining.

Non-metallic inclusions in weld metal have been analysed for the following classes of electrode: E.217, E.614, E.432P, E.356 and an experimental electrode, and for the first time, ferrotitanate has been identified in weld metal. Increase of arc length has been found, in general, to cause more slag inclusions. The effect of arc length on inherent (not slag) inclusions was examined,



Fig. 2.—Microscope room showing Reichert M.E.A. camera and Zetopan microscope.



Fig. 3.—Part of experimental laboratory for work on light alloys.

but was found to be insignificant. A titanium target has been used for the first time in micro-radiographic inspection of inclusions.

High-Tensile Alloy Steels

A series of about 40 experimental alloy steels containing manganese, nickel, chromium and molybdenum has been tested with basic-coated low-hydrogen electrodes. By this means steels have been selected with a 0.3% proof stress of up to 35 tons/sq.in., compared with 25 tons/sq.in. for the best acceptable alloy steel completely weldable with rutile-coated electrodes. Preliminary tests have shown, in the case of two alloy steels, that there is great advantage in quenching and tempering, since the weldability is well maintained in materials having good tensile properties and very satisfactory impact strength.

In dilatation experiments, tests on specimens artificially charged with hydrogen by electrolysis have shown that hydrogen depresses the end-of-transformation temperature. It has been established that, when using low-hydrogen electrodes, there is a critical end-of-transformation temperature of 245°C., and with figures below this value it is impossible to weld without hardened-zone cracking. Previous work had given a figure of 290°C. for rutile electrodes. With the knowledge that end-of-transformation temperature is closely related to weldability, has come the need for a more rapid assessment of this value. This has been accomplished by means of a special dilatometer, in which strain gauges are used to convert linear movement to electrical impulses: these are then fed into a "function plotter" on which the dilatation curves are directly recorded. This apparatus is shown in Fig. 7.

Cracking in Welded Gas Mains

Some cracking has been obtained using a synthetic mixture of H_2S , NH_3 and HCN , and it is hoped that this will correlate with the corrosion cracking which occurs



Fig. 4.—Baldwin-Tate-Emery 200-ton universal testing machine.

in practice in gas plant. This may well prove a successful culmination to a long and patient investigation of these factors.

Oxygen Cutting

A major difficulty in investigating the fundamentals of oxygen cutting is the separation of the contributions



Fig. 5.—Sciaky 3-phase spot welding machine.



Fig. 6.—Tests at high temperature on mild steel weld metal.

from the iron/oxygen combustion and from the pre-heating flame. Experimental work previously carried out has investigated the former only. More recent work has been directed towards the use of the pre-heating flame only. Some aspects of the cutting of cast iron are also being examined.

Fusion Welding of Aluminium Alloys

Investigations have continued on the metal-arc welding of medium strength H.10 alloy, the argon-arc welding of high strength heat-treatable aluminium alloys, and the self-adjusting arc welding of the Al-Mg alloy NP5/6.

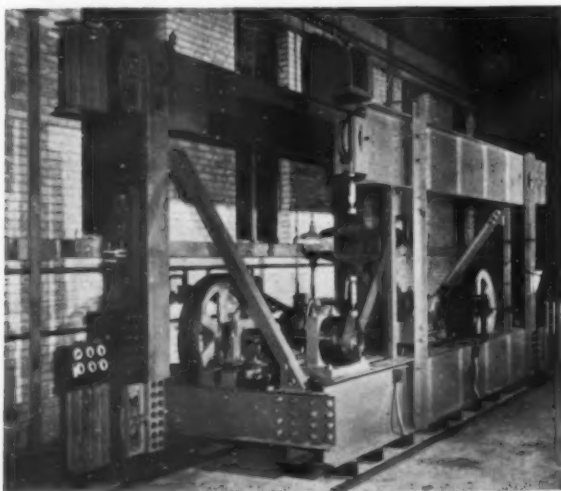


Fig. 8.—Illinois fatigue testing machine.

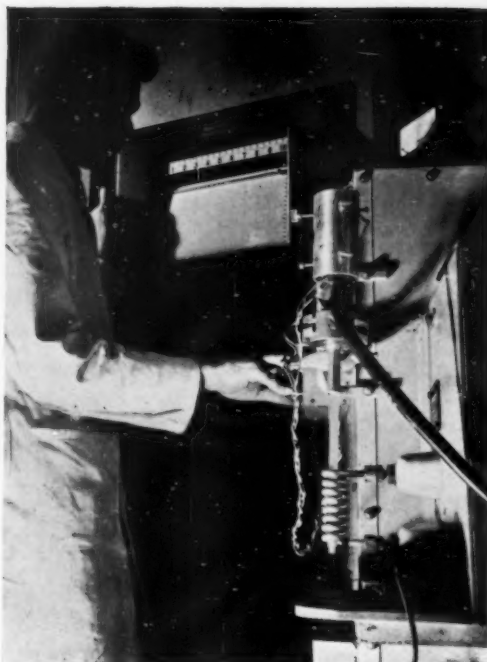


Fig. 7.—Dilatometer and "function plotter" for direct recording of dilatation curves.

A knowledge of the thermal cycle is of importance in all programmes, and a valuable mathematical analysis of heat flow in plates of finite size has been made, which is now being checked by practical measurements of temperature in the parent plate and weld pool. Special techniques have been developed for recording thermal cycles, and equipment is available for the estimation of surface and intrinsic hydrogen in wire and plate material. A simple microscopic method has been developed for the classification and quantitative estimation of porosity in weld metal, and a correlation is being made between available hydrogen porosity and mechanical properties for a range of cooling rates.

The effects of dilution of the filler metal by the parent plate in determining the composition of weld metal has been shown, and a knowledge of the extent of dilution under practical welding conditions has provided a solution to the problem of cracking encountered in the metal-arc welding of H.10 alloy. Such knowledge has also facilitated the selection of filler metals suitable for welding high-strength alloys. By this means a useful improvement in properties has been obtained for welds in duralumin-type alloys, and in Al-Zn-Mg-Cu alloys.

A clear picture has now been given of the factors controlling the degree of arc self-adjustment in the self-adjusting arc process. Work in co-operation with the British Electrical and Allied Industries Research Association has resulted in the construction of improved power sources, the availability of which will have an important effect on the industrial application of the process.

Engineering Researches

Load-Carrying Capacity of Frame Structures

The field of stanchion design has been examined in a recently-prepared review. Extensive data on the

behaviour of stanchions bent about the minor axis have been obtained using an electronic computing machine made available by the mathematics laboratory of Cambridge University. A tentative design method for stanchions bent about the major axis has been completed, and a start has been made on a further series of trials to test its adequacy. The minimum weld sizes required for riveted joints have been determined for a number of conditions, and good correlation obtained with a theoretical treatment of the problem.

Welded Structures under Dynamic Loading

A fatigue investigation, using a pulsating tension load cycle, and up to two million reversals, has been made on plain plates in $\frac{1}{2}$ in. and $1\frac{1}{2}$ in. thick mild steel, and also on manual metal-arc butt welds on mild steel in the same thicknesses. The fatigue limits established by these tests were 13-14 tons/sq.in. for the unwelded plates and 9.5 tons/sq.in. for the butt-welded plates. This work has been done using the Losenhausen machine: it is perhaps not so well known that an Illinois machine is also in use on some of the fatigue investigations, and this is shown in Fig. 8.

Alternating bend (minor axis) tests have been completed on some thin gauge box sections, and a test in progress is shown in Fig. 9. Further work will be devoted to investigating the behaviour of these box sections under alternating torsion. Preliminary tests have been made on argon-arc welded specimens using butt welds, fillet welds and bead-on-plate specimens.

Welded Pipes and Pressure Vessels

A pressure vessel which has been previously tested very extensively has now been fitted with six nozzles, with variations in the type of reinforcement, and the new series of tests is designed to examine the rival merits of these variations (Fig. 10).

An equal branch welded connection, reinforced with a collar, has been analysed when subjected to four different loading conditions, and a similar connection with "triform" reinforcement is under test. Difficulty was experienced in obtaining a butt weld between the bend and the tangents which did not fail before the bend, but this difficulty has now been overcome, and both pulsating pressure and bending fatigue tests have been completed and S-N curves plotted. Ancillary equipment for tests under combined bending and internal pressure has been made.

Residual Stresses and Brittle Failure

Tests are now under way on the brittle fracture of wide plates, 36 sq.in. cross section, for which purpose equipment has been designed capable of applying a total force of 600 tons, evenly distributed.

Docherty's classic experiment on "size effect," in which, with successively smaller geometrically similar notch specimens, failure suddenly changes in character from brittle to ductile, has been repeated and confirmed, and an explanation has been put forward accounting for this effect. Also, for the first time the velocity of propagating cracks has been theoretically predicted, and the result corresponds fairly well with experimental observations.



Fig. 9.—Bending fatigue tests on thin gauge box sections.

The work on the efficacy of various stress-relieving treatments on impact strength has been completed. A range of specimens has been tested with a rail-testing tup hammer, and the results reported to the committee. Cooling tests on a restrained weld did not produce brittle fracture—contrary to an earlier experiment where there was less control of the cooling rate.

Resistance Welding

Projection, Spot and Stud Welding

Probably the most important work in this section is concerned with the development of satisfactory codes of practice. In the case of projection welding, a recommended code of practice has recently been published, and a revised code of practice has been issued dealing with the technique for spot welding low-carbon steel. In addition, work is now in hand to produce satisfactory



Fig. 10.—Testing pressure vessel nozzles with various types of reinforcement.

recommendations for the projection welding of sheet thicker than 14 gauge and thinner than 20 gauge, to extend the previous work.

Experimental and theoretical work has been continued on the thermal effects associated with the spot welding of ferrous materials. Mathematical analysis of this problem has been particularly useful, and the object of this work will be to correlate the conditions of spot

welding with the metallurgical characteristics of the joints produced. A new committee has been set up to examine generally methods for testing resistance welds. It has been agreed to include testing procedures for shear, tension, torsion, hardness and micrographic examination. The investigation of the spot welding of high-strength aluminium alloys is now complete, and a full description of the work has been published.

The British Ceramic Research Association

By A. E. Dodd, Ph.D., M.Sc., F.R.I.C.

Head of the Information Department

As in previous articles on the work of the British Ceramic Research Association, a survey is made of one aspect of the Association's work for the metallurgical industry. On this occasion reference is made to the action on the refractory lining of blast furnaces of alkalis present in the burden and carbon monoxide present in the stack gases.

AT a Council Meeting of the former British Refractories Research Association (since 1948 merged in the British Ceramic Research Association), held in August 1920, a programme of research was adopted; it included:

Blast Furnaces—general requirements from the refractories in the different zones of the furnace... the abrasion and disintegration of firebricks... the use of carbon bricks in the hearth lining.

In those early days the staff numbered about half-a-dozen, and other items of the research programme—particularly a much-needed general evaluation of the properties of refractories—were rightly given priority, so that another ten years elapsed before a start could be made in the wide field encompassed within the narrow paragraph of the original research programme.



Fig. 1.—Top of the stack of a blown-out blast furnace showing abraded and disintegrated brickwork.

The Disintegration of Blast-Furnace Stacks by Carbon Monoxide

Research began with a survey of the behaviour of refractories during service in the blast furnace, coupled with a simultaneous scheme of laboratory work. From reported experience and the actual examination of blown-out linings, it was clear that disintegration of blast-furnace stack linings by carbon monoxide was a major cause of the blowing-out of blast-furnaces for repair. That carbon monoxide dissociates at 400°-500° C., and in so doing deposits carbon, had been known for over half a century; it had also been proved that some forms of iron or its compounds speed up this dissociation and deposition of carbon. The early work of the Research Association showed that the tendency of a firebrick to disintegrate when exposed to carbon monoxide is not determined by the quantity of iron, expressed conventionally in terms of Fe_2O_3 , that the brick contains. A more positive finding, and one that the manufacturers of blast-furnace refractories could apply immediately, was that iron combined as a silicate or complex alumino-silicate glass had a negligible catalysing effect on carbon monoxide dissociation; it was demonstrated in the laboratory that iron contained in a firebrick can be rendered inert in this manner by firing at a high temperature. It was also shown that dilution of carbon monoxide with carbon dioxide and/or nitrogen (simulating the composition of the stack gases in the blast furnace) reduces the tendency of the monoxide to dissociate; this finding was in agreement with deductions from the Law of Mass Action.

At this stage the mechanism of carbon-monoxide attack was thought to have been laid bare, but it again became a live research problem when it was suggested that the ferruginous glass formed during the hard firing of blast-furnace lining refractories might be unstable under certain conditions, and so might again become catalytic to the dissociation reaction of carbon monoxide. The stability of this glass under various conditions of atmosphere was therefore examined in the laboratory, and it was shown that exposure to temperatures between 900° C. and 1,100° C., in either strongly reducing or strongly oxidizing conditions, can decompose a complex ferrous glass; if iron oxide or metallic iron is set free in this way, it may act catalytically on carbon monoxide,

when, and if, the temperature again falls to 400°–500° C. Although temperatures as high as 900°–1,100° C. are unusual in a blast-furnace stack, except at the front of the brickwork near the base, we have recorded such temperatures when a furnace had been working unevenly, and "channelling" had occurred. However, instances of the eventual breakdown by carbon monoxide of blast-furnace linings built of bricks that have withstood the laboratory test for 400 or more hours are rare, and it can be stated with some confidence that the laboratory test remains a very good guide to the suitability of a fireclay refractory for this type of service.

Our latest research in this field has been made possible by the development of the electron-microscope technique. The carbon in a disintegrated firebrick was examined under the electron microscope by R. J. Slawson, of the research staff, and was found to have a characteristic worm-like appearance (Fig. 2). The carbon "worms" vary in thickness from 100Å to about 0.2μ; they are generally somewhat helical and many of the thicker threads consist of a number of thin strands twisted together to form a "rope." X-ray examination of this deposited carbon (by F. G. Wilde) showed amorphous carbon, cementite and iron percarbide, suggesting that the dissociation of carbon monoxide may be catalysed, either by iron, which is alternately converted to cementite and back to iron, or by cementite, which is alternately converted to the percarbide and back to cementite; the catalyst is carried forward at the extremity of the growing thread of carbon, as can be seen from the electron-micrograph, and this explains the coalescence of multiple threads and indicates the mechanism by which the carbon can penetrate refractory bricks.

The Action of Alkalis

The influence of alkalis (present in the burden) on the lining of a blast-furnace has also been investigated. When a blown-out furnace is examined, alkali cyanides are sometimes found within the lining, and there is evidence that alkali attack can start the building-up of a "scaffold" within the furnace. As much as 20% of alkalis have been detected behind some "scaffolds," and micro-examination has shown that alkali aluminosilicates (leucite, nepheline, kalsilite or kaliophilite) may have formed by reaction with the brickwork, reducing its surface refractoriness to 1,400°–1,500° C. This concentration of alkali aluminosilicates is likely to give rise to a sticky surface on the brickwork, to which some of the burden will adhere; thus the beginning of a "scaffold," interruption of the smooth descent of the burden, "channelling," and possible further disruption of the stack lining.

Alkali vapour is also present in small traces in the blast-furnace gas used to heat the hot-blast stoves, and we have observed the same series of alkali aluminosilicates in corroded jointing material in stove linings, as we had previously detected in blast furnace linings. Laboratory experiments have shown that hard-fired aluminous firebricks are more resistant to alkali attack in this way than are siliceous firebricks.

Other Research for the Metallurgical Industries

As in most of our previous articles on the work of the Research Association, we have again concentrated on a single topic. Several of the lines of research discussed in recent years are still being actively pursued; for example the "bursting-expansion" and creep properties of

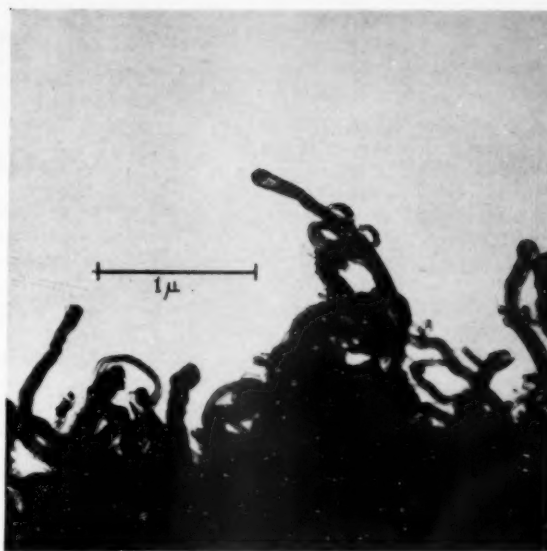


Fig. 2.—Electron micrograph of carbon deposited in a disintegrated firebrick. ($\times 25,000$)

chrome-magnesite refractories are being studied as part of the co-operative investigation on all-basic open-hearth furnaces, and the thermal conductivity of refractories is being measured at mean temperatures up to 1,250° C. Research is also proceeding along lines not previously discussed; some of these will probably form the basis of a future article in this series.

New Transporters at Bidston Dock

Two huge electrically-operated transporters, each weighing 600 tons and of unique design, have recently been put into operation at Bidston Dock, Birkenhead. They are to be used for unloading iron ore from ships at the dockside into waiting road, rail or barge transport for despatch to the Hawarden Bridge Steel Works, near Shotton, of John Summers and Sons Ltd. Each grab has a capacity of six tons, and the time taken to pick up and discharge a grab-load is 60 seconds, giving each transporter a capacity of over 350 tons an hour. Working throughout the whole twenty-four hours, these giant transporters will help considerably to ensure a speedy turn-round of ships and a smooth flow of raw materials into the Shotton steelworks.

The 140-ft. high transporters have a number of interesting features. They are, for example, the only two in Great Britain which can unload either on to land or into barges, the length of the transverse boom—219 feet—allowing the grab to discharge into barges lying on the off-shore side of the ships. The transporters themselves can move along the quay on rails for a distance of 1,000 ft.

The construction of the transporters has been the responsibility of Joseph Booth and Bros. Ltd., whilst the whole of the current collecting equipment, which possesses a number of interesting features, has been designed, manufactured and installed by British Insulated Callender's Cables Ltd., and its subsidiary British Insulated Callender's Construction Co. Ltd., in association with R. and J. H. Rea Ltd., Joseph Booth and Bros. Ltd., and Wm. Cory and Sons Ltd.

The British Iron and Steel Research Association

The wide field covered by B.I.S.R.A. makes it impossible in a short article to do other than mention briefly a few of the more interesting projects. Those featured in the present survey include cooling of blast furnace hearths, sintering, continuous casting, open hearth burner design, lubrication in wire drawing, stretcher strain markings, corrosion of low alloy steels, and ore wagons.

A MAJOR event in the short history of the British Iron and Steel Research Association since it was founded in 1945 was the official opening by H.R.H. the Duke of Edinburgh on November 19th last year of its newest and largest laboratories, in Sheffield. Other laboratories were already in existence at Battersea, Swansea, and Normanby (near Middlesbrough).

This geographical dispersion of resources is deliberate, as is the disposition of B.I.S.R.A.'s work among five autonomous divisions: Iron Making, Steel Making, Mechanical Working, Plant Engineering and Metallurgy (General). There are, in addition, the two departments of Chemistry and Physics, which give assistance to the divisions. The purpose of this arrangement is to enable the Research Association to work as closely as possible with the industry.

It is impossible in a brief review such as this to refer to more than a small fraction of the work now in progress or recently completed. The topics set forth below are merely a representative sample taken from a large number of investigations.

Underhearth Cooling for Blast Furnaces with Carbon Hearths

The resistance to chemical attack and non-wetting properties of carbon make it an excellent material for lining the hearth of a blast furnace, but there are certain disadvantages, such as the "floating" of the carbon

blocks of the hearth bottom, and the overheating and consequent weakening of concrete foundations. Both these shortcomings result from the fact that carbon has a higher thermal conductivity than firebrick. The base of a carbon hearth therefore becomes hotter than that of a firebrick one, and consequently the depth to which liquid iron can penetrate joints in a carbon hearth is greater.

Very little was known about the temperature distribution in blast furnace hearths when B.I.S.R.A. began to study the problems associated with the use of carbon.

The most obvious approach was to insert thermocouples in the brickwork of operating furnaces, and this was done, but such measurements are limited and the accumulation of results is slow. A mathematical treatment of the problem is complicated and the calculations are cumbersome. Two laboratory analogues were therefore devised to estimate the rate of heat transfer in furnace hearths.

One of them was a 1/55th scale model of a hearth and its foundations, heated electrically. On it a campaign life of 2½ years could be reproduced in 8 hours. The other, an electrical analogue, uses a network of resistances through which a current is passed, simulating the flow of heat through a furnace hearth. The voltage at any point in the network is analogous to the temperature at the corresponding point in the hearth. By adjusting the resistances in this network, the effects of changes in any of the variables can quickly be ascertained.

Good agreement was obtained between the results obtained from the analogues and from measurements on actual furnaces. In fact, it has been found that the amount of the deviation of measured hearth temperatures from the predicted values can be used to estimate the extent to which the hearth brickwork has been eroded. As a result of these studies, a method of under hearth cooling has been proposed which would use air circulated through pipes placed below the base of the carbon pad. Only a few horsepower would be needed to drive the fan for circulating the air, and the method would therefore be cheap as well as simple. Water cooling, already in use on the Continent, is not favoured.

Sinter

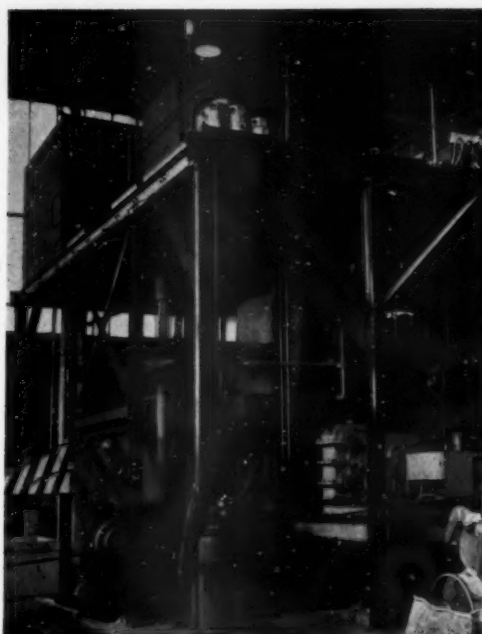
A great deal of the iron ore used today, especially that which is imported from abroad, is finely divided, and if put in a blast furnace in its raw state would upset the gas



The main building and the metal working shop at the B.I.S.R.A. Sheffield Laboratories.

Left—Pilot plant for continuous casting in action at the Sheffield Laboratories.

Right — Continuous casting plant at William Jessop & Sons, Ltd.



distribution in the furnace, or would be ejected with the top gases. One solution is to sinter the ore.

An increasing amount of this finely divided ore has to be used, and sinter production in Britain is therefore rising rapidly: 4.6 million tons were made in 1950, while it is estimated that in 1954 6 million tons will be made, and in 1956 8 million tons. By 1958, sinter is expected to provide nearly 30% of the iron-bearing portion of the burdens of British blast furnaces. One of the largest works in the country is now regularly using sinter alone, without any untreated ore, in blast furnace burdens, and as a result has saved nearly 5 cwt. of metallurgical coke for every ton of iron made.

Research on sintering was stimulated by the urgent need to prepare much of the 10 million tons of ore imported every year, and by the prospect of increased production which a wider use of sinter offered. When B.I.S.R.A. began to study the process, it had first to discover the causes of variations in the quality of sinter, and then to find out how to control them. The first part of the work, completed some years ago, showed that the amount of carbon present in the sinter mixture and the thoroughness with which the materials were mixed were the two dominant factors affecting the quality of sinter. It was next shown that the output of a plant is controlled largely by the permeability of the sinter bed—the ease with which air can pass through it. Sufficient air must be drawn through the sinter mixture to burn the fuel in it, and the less permeable the bed, the greater the power required to do this. The total volume of air needed was shown to depend on the composition of the sinter mixture. If the permeability of the bed can be increased, more air can be drawn through it in a given time, and combustion will be more rapid. The easiest way to control the permeability is to vary the amount of moisture in the mixture; adding water increases the permeability and enables the mixture to be sintered more rapidly. There is, however, a limit to this; if too much water is added, the permeability falls again, and

it also becomes difficult to ignite the mixture. The latest sinter plants are provided with means of measuring permeability continuously, and the operator can then compensate for any fluctuations by adding more or less water.

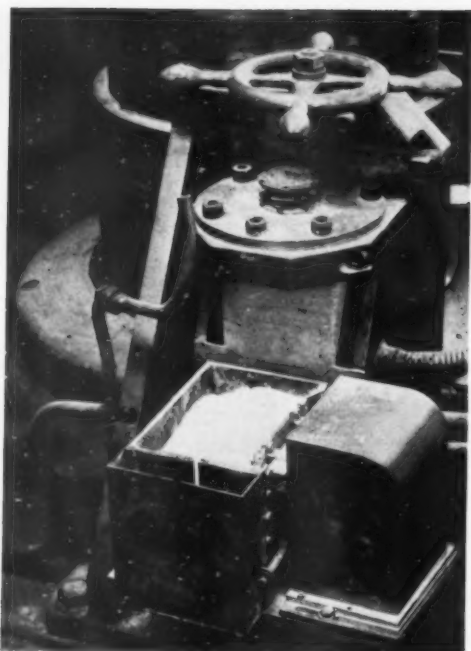
Much can still be achieved with existing plant. One member firm asked for the Association's help in an attempt to increase production in a large plant from 16,000 to 20,000 tons per week. Within six months, 23,000 tons per week were being produced, and this performance has since not only been maintained but increased to 30,000 tons per week.

Increased output brings in its train another problem—that of cooling the hot sinter. To do this on the strand is wasteful, and to use water for cooling sinter lowers its quality. This problem has been studied by B.I.S.R.A., and the investigations have shown the importance of breaking and screening the sinter before cooling to increase its permeability. Several firms have installed sinter coolers which obviate the need for water cooling.

Continuous Casting

A two-strand pilot plant for continuous casting is now in operation at the Sheffield works of William Jessop & Sons Ltd., and 4 in. square billets of high speed, stainless, and other alloy steels are being continuously cast. This plant has been financed by a group of eleven firms, and its design is the result of seven years theoretical and experimental work by B.I.S.R.A.

The continuous casting of non-ferrous metals was accomplished many years ago, but the higher melting point of steel makes it difficult to keep it liquid in the runners between the ladle and the mould, and the lower thermal conductivity reduces the rate of growth of the solidified skin, thus making it difficult to prevent rupture of the solidified skin as the billet is withdrawn from the mould. After a detailed study of the fundamental problems of mould friction, heat transfer, and rates of solidification by the Physics Department of B.I.S.R.A.,



Vibrofeed equipment for wire drawing lubricant. The electromagnet is under the cover at bottom right.

a water-cooled mould mounted on springs was evolved, and a laboratory plant was built. A special copper alloy was found to be a satisfactory material for the mould itself.

This preliminary work took considerable time, but it provided a solid foundation of knowledge which could not have been obtained by any other means, and which enabled the subsequent work to go forward rapidly and without time-consuming difficulties of the kind which arise from lack of basic facts.

The pilot plant now in operation at Sheffield is designed to produce two 35 ft. billets, one from each of the two strands, from each furnace charge of about $1\frac{1}{2}$ tons. This represents a yield of about 90% of the charge—a ratio which makes continuous casting particularly attractive for highly-alloyed steels.

Other plants are already operating in Britain under foreign patents; this new plant is quite independent of them and the way now lies open to unhampered full-scale development of continuous casting in Britain.

Open Hearth Burner Designs

Considerable success has been achieved with new designs of burners for open hearth furnaces. Most burners use a jet of steam to atomise the oil and accelerate the droplets. The international flame radiation trials at IJmuiden in Holland revealed that for maximum efficiency it is not sufficient for the oil to be effectively atomised, but that the droplets should also be so accelerated that they attain the velocity of the steam with the least possible slip. The energy losses are then at a minimum, and much less steam is needed.

A prototype burner was constructed in which the oil was accelerated in a conical tube 14 in. long before entering a nozzle 4 in. in length. Laboratory tests were encouraging, and a simplified version of this burner was then developed for use in steelworks. This works version dispenses with the conical tube and uses a tapered nozzle

about 5 in. long. A further modification has been made for burning a mixture of coke-oven gas and liquid fuel.

The two types of burner are now on trial in the works of two member firms. One firm has saved fuel and has at the same time substantially increased the life of its furnaces, while the other has maintained the same driving rate and has used 10% less fuel than before. The success of these preliminary trials has been such that both firms are now fitting these burners to all the furnaces in their melting shops. The simplicity of both types considerably reduces maintenance.

Lubrication in Wire Drawing

Inadequate or ineffective lubrication during the drawing of wire or rod can result in damage to the stock. A method of indicating continuously how effective or otherwise is the lubrication within the die is being developed by B.I.S.R.A. It involves the measurement of the electrical resistance of the lubricant film between the wire and the die; the lubricants used are poor conductors, and the thicker the film, the greater the resistance. Measurements have been made at high and at low speeds, and trials under works conditions have yielded satisfactory results.

One cause of bad lubrication is "channelling" of the soap in the hopper by the ingoing wire or rod. When this happens, the stock runs freely through a smooth-walled channel without picking up sufficient soap. If the wire drawer watches the hopper closely and stirs the soap at frequent intervals, this can be avoided, but even serious channelling may not always be obvious to the eye.

The system devised by B.I.S.R.A. to eliminate channelling is called "Vibrofeed"; it uses a hopper with a plate, which forms part of one side and of the floor, mounted on rubber strips. An electromagnet is used to vibrate this plate and agitate the soap in the hopper. Not only does this prevent channelling, but if fine soap powder is used and the frequency of vibration is carefully chosen the soap can be made to adhere more firmly to the wire. In one experiment in which soap powder of 100 mesh was vibrated at 10 cycles per second, the powder could only be removed from the wire by vigorous scraping.

The Prevention of Stretcher Strains in Steel Pressings

B.I.S.R.A. is now carrying out research which aims at preventing the onset of the defect known as "stretcher strains" in mild steel pressings. These markings are formed during pressing when some parts of the metal yield plastically while others are only strained elastically. The tendency of stretcher strains to be formed is intimately connected with the discontinuous yield point, and their severity depends on the yield point elongation; if the elongation is large, the stretcher-straining is severe. The yield point, and with it the tendency to form stretcher strains, can easily be removed by working the steel slightly before pressing. This is usually done by temper rolling, i.e. by rolling to a reduction of 1-2%, but if the yield point elongation is not too large, roller levelling is also suitable. This usually consists of bending the sheet severely over a flexing roller and then flattening it by passing it through a series of staggered rollers. The yield point can also be removed by stretching the sheet to a strain greater than the yield point elongation, but this method is not much used in industry.

The relation between stretcher strains and the stress-strain curve has been studied, and the use of the yield point elongation (determined in a tensile test) to assess the tendency to form stretcher strains has been substantiated.

If the steel sheet is allowed to rest at room temperature for some time after being worked to remove the yield point, it is found that the yield point returns and a pressing will show stretcher strains. This phenomenon is called strain ageing, and it occurs to some extent in most mild steels. To speed up the ageing tests, accelerated strain ageing at elevated temperatures was used, and an expression relating the ageing times at two different temperatures was derived from theoretical considerations and confirmed by experiment up to 200° C. Thus, one hour's ageing at 100° C. was found to be equivalent to six weeks at 21° C. or three months at 15° C.

It has been shown that the residual stresses introduced into sheet metal by rolling are higher than those caused by roller levelling or stretching; this is why temper rolling is more effective in preventing a return of the yield point than either of the other two processes. These residual stresses mask the yield point elongation and prevent stretcher strains from forming, but the basic process by which the metal ages after being worked, resulting in an increase in strength and a decrease in ductility, has been shown to be the same in all three processes.

It has been demonstrated that both macroscopic and microscopic residual stresses can have a very profound effect on the form of the initial part of the stress-strain curve for mild steel. A reduction of the macroscopic residual stresses might be expected to accelerate the return of the yield point, and light roller levelling immediately after temper rolling was found to have this result. The effect depends on the temper rolling reduction, and is most marked for higher reductions, when temper rolling is most efficient. Heavy roller levelling at low rolling reductions delays the return of the yield point, but is detrimental at higher reductions. A heavy flexing and rolling treatment is as beneficial as a high rolling reduction.

Corrosion Resistance of Low Alloy Steels

The measurement of rates of corrosion by exposure tests is inevitably a slow process. An investigation into the corrosion resistance of low alloy steels has recently been completed; most of the tests were of five or six years duration, and some of them were begun as long ago as 1938. Steels of nearly sixty different compositions were exposed, and the data yielded have enabled the resistance to corrosion of low alloy and other steels to be compared in quantitative terms. The tests have shown that when exposed to the atmosphere the rate of corrosion of steel containing 0.3% copper and 1.0% chromium is not more than a third of that of ordinary mild steel. Small additions of alloying elements are less effective against corrosion of steel immersed in sea-water, but the rate of corrosion is halved by the presence of 3% chromium, and there is some evidence that additions of aluminium and beryllium may also be beneficial. There is little difference between steels containing varying amounts of carbon, and the effect of heat-treatment is negligible. Steels containing copper are no more resistant than ordinary mild steel when continually immersed in water, but some practical

experience of the water-line corrosion of the hull plates of barges indicates that copper steel may be slightly superior under these conditions. Cast iron was also tested; exposed to the atmosphere, it rusted less rapidly than unalloyed low carbon steel, but in sea water the rate of corrosion was much the same, graphitization taking place.

In addition to the exposure trials, accelerated tests were conducted in the laboratory, but it was found impossible to correlate the results with those obtained from outside exposures. At the present time there seems, therefore, to be no alternative to outdoor exposure trials.

These low alloy steels are not rust-proof, but the rust layer which forms on them is less permeable than that which forms on ordinary steels, and further corrosion is consequently retarded. Their properties are of special value in situations where conditions are severely corrosive, and where adequate protection by means of paint is impracticable or even impossible. The steel floor of a railway wagon provides a good example. Service trials have indicated that floor plates of low alloy steel should last at least twice as long as similar ones made of mild steel. A steel containing about 0.3% copper is similarly suitable for plates for railway sleepers. Other uses of low alloy steels include fencing wire and thin steel sections which cannot conveniently be repainted after they have been erected.

Railway Wagons for Iron Ore

As part of a large-scale investigation into methods of handling imported iron ore, B.I.S.R.A. has made a study of the design of railway wagons for carrying this traffic. The continued use of 2-axle wagons in Britain while 4-axle wagons are widely employed in America and on the Continent has often been the subject of comment, because a train carrying a given weight of ore in these larger wagons is lighter and shorter, and contains fewer units to handle. To make a true comparison, wagons with different numbers of axles were considered, taking account of the limitations of the British loading gauge and axle loading limits. The results of this study have vindicated current British practice.

Four-axle wagons are favoured by a large loading gauge, low axle loading, and by loads having high bulk density. Thus, with the present British axle load limit of 17½ tons, a train of 4-axle wagons would be slightly shorter than one of 2-axle wagons carrying the same weight of home ore. Larger tipplers and weigh-bridges would, however, be needed to handle bogie wagons. If the axle loading is increased to 22½ tons, as is hoped, then for home ore a train of 4-axle wagons would be no shorter than one of 2-axle wagons. The case for 2-axle wagons will be strengthened still further if improvements in the design or construction of wagons enable tare weights to be reduced.

Imported ore has a greater bulk density than home ore, and even at the higher axle loading, a train of 4-axle wagons is shorter. Where imported ore traffic is heavy enough to justify a shuttle service with wagons used solely for this one purpose, 4-axle wagons are the better choice from this point of view, although more expensive. 3-axle wagons, as used in Sweden, are a possible alternative.

It is recommended that all new tipplers and weigh-bridges should be able to handle a gross weight of 45

tons, to anticipate an increase in axle load. It is also important that loading gauges in works should not be smaller than those of British Railways.

Other Activities

The Operational Research Section, using a grant from the Mutual Security Agency funds, has set up a team of three men to investigate local problems of firms in the iron and steel industry. Members of this team visit works when asked by the managements, and their observations and recommendations remain confidential to the firm concerned. The problems so far investigated have included ways of increasing the output of scrap-baling presses, the reduction of charging times in open hearth furnace melting shops, and methods of inspection and production control in a wire works. Studies of traffic operation and layout have also been successfully completed at several works.

Another grant from the Mutual Security Agency is being used by B.I.S.R.A.'s Information Section for a study of the flow of technical information into and within the steel industry. This research includes the study of the way in which firms receive, store, distribute, and use new items of research knowledge, such as those from

their own research departments or from B.I.S.R.A. reports, as well as the knowledge received from other sources. Two of the main objects of the work are to make the results of B.I.S.R.A.'s work more readily available in the industry, and to find out how the Association can best serve its members.

The Corrosion Committee formed a Publicity Panel in 1953 to study means of applying more widely the results of the Association's work on corrosion. Papers and articles on the prevention of corrosion have been supplemented by a broadcast talk with the title "The Fight against Rust," and a booklet "The Prevention of Corrosion" has been written, giving a popular account of the work of the Corrosion Committee.

Since the last review of B.I.S.R.A.'s work was published in METALLURGIA a year ago, over 300 research reports and other papers have been issued and circulated, as well as the Tenth Annual Report and the third issue of *B.I.S.R.A. Survey*.

A book "Deep Drawing," an account of the research into this subject done by Professor H. W. Swift and others at the University of Sheffield, was published for B.I.S.R.A. by Butterworths Scientific Publications in June of this year.

The British Cast Iron Research Association

By Dr. J. G. Pearce, O.B.E.

Director of the Association

That practical problems are not neglected by the British Cast Iron Research Association is indicated by the continuing work on the elimination of dust hazards in the foundry, and the investigations into the shell moulding process, to name but two examples. Research work in progress covers a wide range of subjects, including the effect of gases in cast iron, the causes of enamelling defects, and the properties of nodular graphite cast iron.

THE British Cast Iron Research Association held Open Days on 7th and 8th July, this year, and some 300 representatives of member-firms attended on the first day and were welcomed by the President, Sir Frederick Scopes. On the second day, some 150 representatives of other research organisations, Government departments, trade associations, technical institutions, universities, technical colleges and schools were present and were welcomed by the Chairman of Council, Mr. J. J. Sheehan. Charts, diagrams, photographs, working models and demonstrations illustrating work in progress were employed on a scale not previously attempted. An additional feature was a small exhibition of some ninety examples of art castings made in cast iron, mainly of British and Continental origin, in the form of plaques, statuettes, reliefs and other articles for use and decoration (Figs. 1 and 2). The importance of maintaining the skills developed in such work is illustrated by the adoption during the war of the historical lost wax process for making jet engine castings to very fine tolerances in alloys too hard to finish by machining.

During the year, 26 research reports were issued in the Association's *Journal of Research and Development*, and some 16 papers were presented by the Association's staff to various learned societies. The Association participated in the D.S.I.R. exhibit at the Engineering

and Marine Exhibition at Olympia in September 1953 and a Conference in November of that year on Simplifying Foundry Operation was so successful that it had to be repeated. The pre-war practice of arranging occasional visits to Continental foundry centres was resumed in May 1954 when two parties, totalling between 50 and 60 representatives of member-firms, made a tour of a selected group of foundries in Belgium and Western Germany.

Development

The number of enquiries to the Development Department from the industry itself and from users of cast iron is higher than at any previous period in the Association's experience, and that section of the Department dealing with foundry atmospheres is engaged on active experimental work on the foundry knock-out, where the casting is separated from the sand mould. The critical air contours required to control dust plumes under varying shop conditions are being determined. The problem of controlling dust from the conventional pedestal grinder is virtually solved, and the Association's device in the form of an external extractor unit for fitting to existing grinders is in active production by the licensed manufacturer, while another firm is incorporating the device as an integral part of its new machines. Portable hand grinders and swing frame



Fig. 1.—Fruit bowl cast for the Great Exhibition of 1851. It is about 12 in. in diameter, with the interior ornamented with classical figures, and bears the inscription "Art Union of London, 1851."

grinders are now receiving attention, and preliminary work has been carried out on the problem of external atmospheric pollution from the cupola stack by means of a wet arrester.

Research

The successful application of the vacuum fusion method (Fig. 3) for the determination of gases has enabled much useful work to be done in establishing the amounts of oxygen and nitrogen present in the molten metal under varying foundry conditions with reference to melting equipment and raw materials. A vacuum heating method has been evolved for the determination of hydrogen and suitable apparatus constructed. This

work has dispelled some currently held views on the presence and effect of oxygen, and the commonly found effect of adding small quantities of aluminium to molten cast iron is apparently due not so much to the removal of oxygen as to the removal of nitrogen. Oxygen has no direct carbide-stabilising effect, but such an effect may be apparent by combination with other elements.

A good deal of work has been done on the shell moulding process to determine the amount and type of resin required, the type of sand to be used, the influence of clay content, curing temperature, curing time and gas content. Apparatus to produce shell mould test-pieces has been constructed and used. Equipment has also been developed to determine stress-strain curves on normal sand mixtures at the elevated temperatures at which such sands are used in the foundry.

Field tests on the application of cathodic protection to cast iron ship propellers and to buried cast iron pipe lines have been continued.

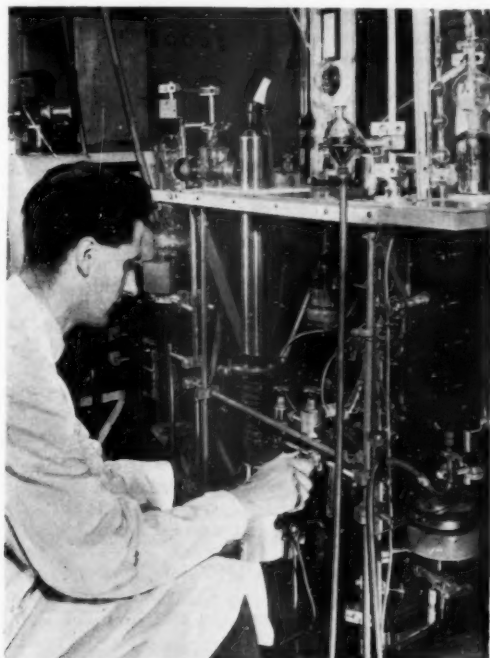


Fig. 3.—Vacuum fusion apparatus for the determination of gases in molten cast iron.



Fig. 2.—Head of Sidney Gilchrist Thomas, inventor of the basic converter steelmaking process, cast by Buderus, Hirzenhain.

The porcelain enamelling process finds wide application in the light castings industry, and a considerable amount of work has been done on defects arising in the process, and on methods for their elimination. Limits for the amount of enamel scrap which can safely be incorporated in furnace charges have also been established.

Nodular cast iron continues to make remarkable progress in its industrial applications. The versatility of this material is illustrated in Fig. 4 (from the author's article in the *F.B.I. Review* of February 1954) and a considerable amount of work has been done on the

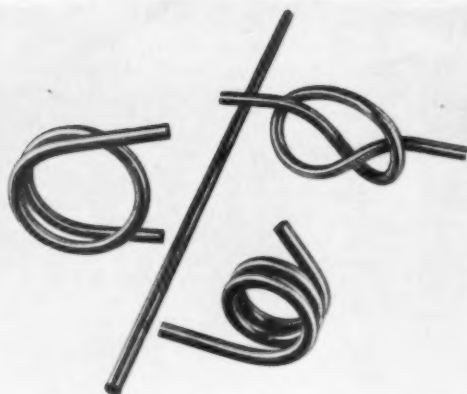


Fig. 4.—Nodular graphite cast iron bars, annealed and bent cold to the shapes shown.

mechanical properties of nodular irons, particularly fatigue and impact. Work on malleable cast irons covers galvanising embrittlement of blackheart, and the sulphur and manganese contents of whiteheart. The preliminary study of low temperature properties, and properties under impact, of nodular and malleable irons has revealed some interesting information concerning

the value of these materials under conditions which promote brittle fracture.

The study of the problem of soundness in iron castings directed attention to the mould, and measurements have been made of changes in dimensions of the mould cavity during solidification, both in dry-sand and green-sand. Progress in studies of the solidification of cast iron were reported in two papers to the Spring Meeting of the Iron and Steel Institute, and these were accompanied by a study of the solidification of iron-carbon-phosphorus alloys, respectively by Morrogh, Morrogh and Williams, and Morrogh and Tütsch.

The Association has collaborated with a number of other laboratories in the industry in improvements in routine chemical analysis. The work of the spectrographic section has been mainly concerned with the application of direct-reading methods, with the determination of small amounts of residual elements, and with the analysis of slags.

Operational Branch

The Operational Team has, since its inception, made over 500 visits to more than 400 foundries, covering about one-seventh of the output of the whole industry. Great appreciation has been expressed of the reports received, and of their value in assisting productivity and operating efficiency.

Properties of Nimonic 95

NIMONIC 95 is a recent addition to the well-known series of alloys, and an extensive survey of properties, particularly long-time creep properties, has not yet been possible. Nevertheless, a considerable amount of data is now available and is given here, together with some extra information on Nimonic 90.

Heat Treatment

The greatest creep-resistance is normally obtained by solution-treating the alloy at as high temperature as possible, but this can sometimes lead to the development of a coarse grain size, depending on the conditions of the prior hot-working. The recommended treatment which gives good creep properties and retains a fine grain size over a wide range of hot-working conditions is as follows

4 hours at 1,150° C., air-cool, followed by
6—8 hours at 1,080° C., air-cool, followed by
16 hours at 700° C., air-cool.

After this treatment, properties of the order shown in Tables I, II and III have been obtained on Nimonic 95.

Initial solution-treatment for 1 to 2 hours at 1,200° C. has been used instead of 4 hours at 1,150° C. when a coarser grain size has not been regarded as unsatisfactory, the later steps of the treatment remaining unchanged.

TABLE I.—SHORT-TIME HIGH-TEMPERATURE TENSILE PROPERTIES OF NIMONIC 95

Property	Temperature ° C.										
	20	100	200	300	400	500	600	700	800	900	1,000
0.1% Proof Stress—tons/sq. in.	51.6	49.3	48.5	46.5	46.3	46.0	44.3	43.0	31.1	17.1	4.12
Maximum Stress—tons/sq. in.	81.9	76.0	77.9	75.1	72.0	72.1	64.7	51.5	40.1	21.9	6.2
Elongation—% on 4√Area	25.1	21.9	20.6	20.6	21.4	23.6	13.7	4.5	4.5	10.9	59.3
Reduction of Area—%	24.1	25.5	21.9	24.6	25.3	28.1	19.5	7.1	6.4	12.5	48.0
Modulus—millions of lb./sq. in.	30.5	29.8	30.6	29.3	29.3	27.3	26.4	25.1	22.0	17.9	14.1

TABLE II.—FATIGUE PROPERTIES—ROTATING BEND TEST

Alloy	Temperature ° C.	Stress—tons/sq. in.	Endurance
Nimonic 90	815 870	0 ± 17.4 0 ± 12.2	45 × 10 ⁶ cycles in about 300 hr.
Nimonic 95	870	0 ± 20 0 ± 16.8	10 × 10 ⁶ cycles in about 65 hr. 45 × 10 ⁶ cycles in about 300 hr.

TABLE III.—CREEP CHARACTERISTICS OF NIMONIC 95

Temperature ° C.	Stress (tons/sq. in.) to Produce Creep Extension of																
	0.1% in				0.2% in					0.5% in				Rupture in			
	100 hr.	300 hr.	1,000 hr.	5,000 hr.	100 hr.	300 hr.	1,000 hr.	5,000 hr.	10,000 hr.	100 hr.	300 hr.	1,000 hr.	5,000 hr.	100 hr.	300 hr.	1,000 hr.	5,000 hr.
750	20	16.5	13	9.2	22	18	14.5	10	8	23	19.5	15.5	10.5	23.5	19.5	16	11
815	11	8.5	6	—	12	10	7.5	—	—	13	10.5	8	—	13.5	11.5	8.5	—
870	7	5	2.7	—	8	6	4	—	—	8.5	7	5	—	9	7	5.5	—
925	—	—	—	—	—	—	—	—	—	—	—	—	—	5.0	3.8	2.2	—

The British Steel Castings Research Association

By J. F. B. Jackson, B.Sc., A.R.I.C., F.I.M.

Director*

The modus operandi and activities of the British Steel Castings Research Association, which was incorporated in April, 1953, and of its predecessor, the Research and Development Division of the British Steel Founders' Association, have previously been outlined. Reference is made in the following article to a selected series of research and development projects upon which the Association has latterly been engaged.

CO-OPERATIVE research within the steel founding industry, which since April, 1953, has been organised by the British Steel Castings Research Association and previously, since 1949, by the Research and Development Division of the British Steel Founders' Association, has progressively yielded results of direct practical application to the manufacturing processes, in addition to a continual flow of basic knowledge and information arising from work of a more fundamental character. At the same time there has been a corresponding response from industry itself arising from the Association's work, evidenced by the increased calls from member firms, both individually and collectively, for advice from the B.S.C.R.A. staff, with particular reference to the practical demonstration of new techniques and process developments, and their industrial application.

It has been a particular feature of the Association's policy since its origin in 1949, to regard as one of its major functions the practical interpretation of its research findings, and, where appropriate, their development at industrial level. Its plans for the establishment of a Foundry Experimental Station in Sheffield, which were announced recently, reflect this policy, since these are aimed at providing facilities not only for an increased volume of research and development activity on a scale directly related to practice, but also for the demonstration of processes, plant and equipment to representatives of its member firms, to an extent that has not been possible hitherto.

In fields of common scientific or technological interest and importance, the B.S.C.R.A. maintains continuous liaison with the research associations of other industries, notably the British Welding Research Association, the

British Ceramics Research Association, the British Cast Iron Research Association, the British Non-Ferrous Metals Research Association and the British Iron and Steel Research Association, established at various staff levels, and, in many instances, through joint research and technical committee operation.

The remainder of this article refers to specific aspects of the work of the Association, which are considered to be of general interest.

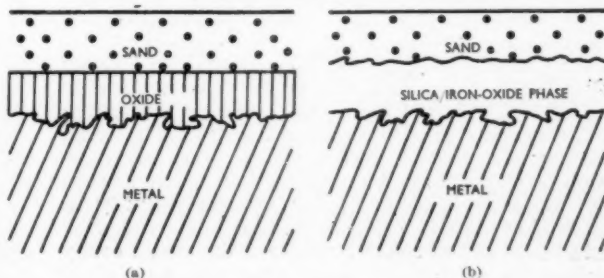
Moulding Sand Adherence to Steel Castings

The Association has continued to support research on the causes of moulding sand adherence to steel castings, notably at the University of Cambridge, where, under the direction of Dr. T. P. Hoar, an attempt has been made to assess the relative importance of sand compaction, sintering, grain size and distribution, binder content and refractory wash in determining the degree of liquid metal penetration of the mould face. To determine the extent to which sand adherence can arise from conditions which may not involve direct penetration of the mould face by liquid metal, further work is now in hand. It has been shown that such adherence can in fact take place, and preliminary work suggests that the phenomenon is due to the "keying" action of a liquid iron-oxide/silica phase which, having on the one hand fused to the mould face, has on the other penetrated and solidified on to an irregularly oxidised and pitted metal surface. (See Fig. 1).

Meanwhile, arising from the Cambridge researches, and from other work conducted by the Association in Sheffield, the development has been put in hand of a non-destructive mould testing technique to determine, before casting, the tendency of individual moulds to metal penetration. The initial work in relation to this project is being conducted under the supervision of Dr.

* Mr. Jackson was Director of the Association at the time this article was prepared, but he has now relinquished this post to join the Board of A.P.V. Paramount, Ltd., of Crawley, Sussex.

Fig. 1.—Schematic diagram showing suggested mechanism of sand adherence to steel castings, under conditions not involving penetration of the mould wall by liquid steel: (a) pitting of the casting surface due to uneven oxidation; (b) formation of low melting point, iron oxide/silica phase which, having fused to the sand of the mould face, has also penetrated the irregularly oxidised surface of the metal.



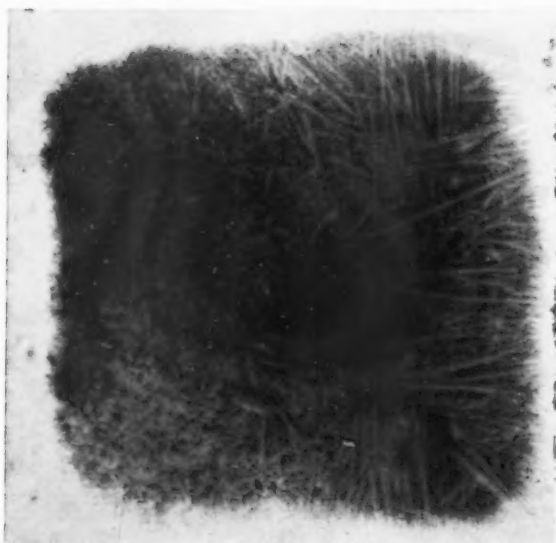


Fig. 2.—Autoradiograph of experimental steel casting fed from a heat containing a small quantity of radioactive iron. The dendritic pattern is due to the presence, as an impurity, of traces of radioactive phosphorus in the activated sample of iron.

J. White of the Refractories Department of the University of Sheffield.

It may be noted that work under this general heading has an important bearing, not only upon production costs, but also upon the problem of reducing the airborne dust concentrations which inevitably arise during fettling operations.

Mechanism of Freezing of Steel

Previous reference has been made to the Association's fundamental researches into the mechanism of freezing of steel in refractory moulds, and 1953 saw the termination of two major projects in this field, one sponsored at the Royal School of Mines in London and the other at King's College, Newcastle upon Tyne. Subsequent work has primarily been aimed at analysing and correlating the various researches on freezing phenomena which the Association has been pursuing over the past four years, and relating these to parallel investigations conducted elsewhere, notably in America.

The technique first employed by the Association at King's College, Newcastle upon Tyne, in which an attempt was made to study the feeding and freezing processes by means of radioactive tracers, has aroused considerable interest, and forms the subject of continued investigation by the Association. The application of this technique, which undoubtedly has attractive possibilities, is still attended by a number of practical difficulties which have not yet been fully resolved, and the purpose of the present study is to define the conditions under which the technique can be regarded as of value when applied to the study of feeding and freezing processes in steel castings. As an example of the type of practical difficulty encountered, Fig. 2 illustrates an autoradiograph of an experimental steel casting, which was fed from a feeder head containing a small quantity of dissolved radioactive iron. While the widespread distribution of the tracer throughout the mould cavity confirms the existence of strong convection currents in



Fig. 3.—Photomicrograph of sample of steel exhibiting intergranular fracture. Coarse needles of aluminium nitride growing into adjacent grains. x800

the molten steel, the small quantity of radioactive phosphorus present in the tracer as an impurity has segregated in the casting to give rise to the strong dendritic pattern clearly visible, and illustrates an aspect of the technique which forms the subject of current investigation.

In addition to the importance which, as a result of this work, is now attached to convection, more recent studies have clarified the process of dendritic growth in steel castings, and shown its dependence upon casting size, pouring temperature, gravitational influence, and feeder head geometry. Moreover, variations in the cast dendritic structure arising from variations in the influence of these factors have been shown to have a bearing upon the mechanical properties of the casting. Fundamental consideration of the process of dendritic growth has, therefore, a direct bearing upon, and significance in relation to, the production of steel castings required to meet the most severe conditions of service.

Intergranular Fracture

An investigation sponsored by the Association at the University of Sheffield, into the occurrence of intergranular (or rock-candy) fracture in steel castings, has now been completed. The results to a large extent



Fig. 4.—The air-carbon-arc torch, showing samples of gouging. Note the clean, un-oxidised, surface of the cuts.

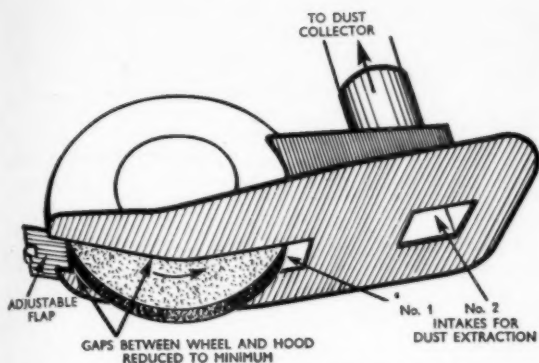


Fig. 5.—Diagram showing principle of B.S.C.R.A. integral exhaust system for swing frame grinders.

confirm earlier American work, in that the fracture, as experienced in foundry steels, can usually be attributed to the occurrence of aluminium nitride, (see Fig 3) although the presence of this material at the grain boundaries cannot always be directly confirmed. The investigation has shown that steel known to possess this particular form of weakness can have its susceptibility to intergranular fracture entirely removed by heating to a temperature of approximately 1,250° C., followed by quenching, although the weakness reappears after slower cooling from the same temperature, especially if the steel is held between 1,140° and 900° C. While the high temperature treatment followed by quenching does not, of course, constitute a practical remedy for the trouble, it does provide an indication of the nature of the problem. The experimental work conducted at Sheffield University, using high-frequency melted steels, does, however, suggest that the occurrence of intergranular fracture can be minimised, if not prevented, by a deoxidation technique incorporating either ferro-titanium or ferro-zirconium, since both titanium and zirconium have a greater affinity than aluminium for nitrogen, and so inhibit the formation and subsequent precipitation of aluminium nitride. The significance of this suggestion remains, however, to be assessed in terms of works practice, and it cannot at the present time be said that the problem is either fully understood, or under completely effective practical control.

Air-Carbon-Arc Gouging Process

An important contribution to the equipment available in this country for the dressing of steel castings has

resulted from the Association's development work in connection with the Air-Carbon-Arc Torch, an illustration of which is shown in Fig. 4. This torch is designed to prepare, for weld repair, locally defective areas of a steel casting, a gouging effect being obtained by means of an electric arc struck between a carbon electrode and the casting, the melted or puddled metal being blown clear by means of a continuous jet of compressed air. By this means, defects such as hot tears, cracks, blow-holes, shrinkage cavities or small sand inclusions may be removed in less time, with greater precision, and with considerably less discomfort to the operator, than is possible by the orthodox method of carbon-arc melting, from which the new torch has been developed. In certain applications, the torch, which can also be employed upon austenitic chromium-nickel and high-manganese steel castings, has been demonstrated to be considerably faster in operation than the pneumatic chisel, as compared with which the freedom from noise and fatigue to the operator is an important consideration. The presence, however, of sand inclusions in any quantity interferes with the operation of the arc, and in such circumstances the pneumatic chisel remains the only practicable solution for the removal of these defects.

The air-carbon-arc torch is simple in construction, as will be seen from the illustration. Both compressed air and direct current are fed through the combined air hose and electric cable to a well-insulated holder fitted with a quick release adjustable clamp for the carbon electrode: the clamp houses two air ports for directing the air jets to the melting zone. The Association has prepared, for its member firms, an instructional film demonstrating the more important operational features of the torch, and has also given, through its staff, practical demonstrations and trials of this gouging process at a large number of different centres throughout the country.

Swing-Frame Grinder Dust Control

The Association established a Dust Research Station in Sheffield in 1951, with the particular object of studying dust suppression problems associated with foundry equipment, in the first case in relation to various types of grinding machines. Widespread reference has already been made in the technical press to the B.S.C.R.A. recommendations for dust control on so-called stand or pedestal-grinding machines, recommendations which have been generally adopted by manufacturers of this type of grinding unit. Latterly, the principles of dust control developed for the stand-grinding type of unit

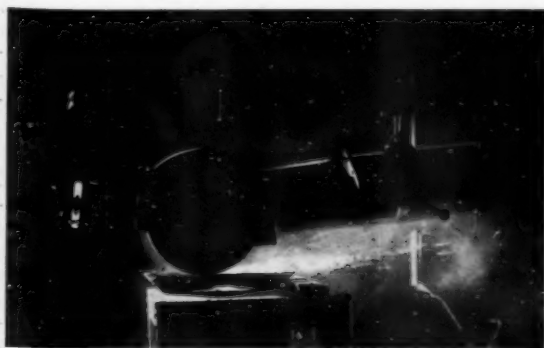
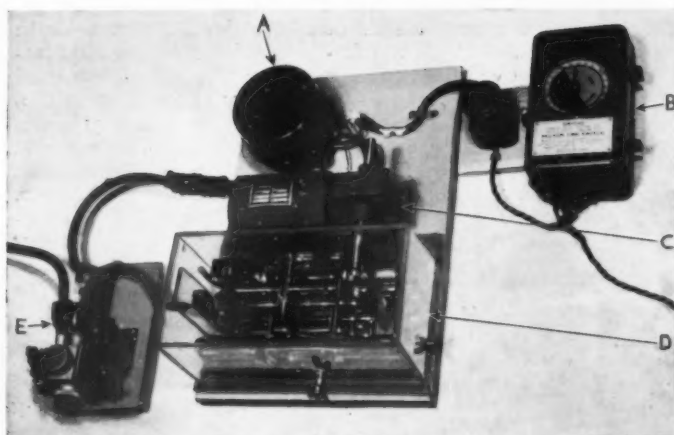


Fig. 6.—(a) Grinding with conventional exhaust system.



(b) Grinding with improved B.S.C.R.A. exhaust system.



A—PULSE GENERATOR (CONTROLLING SAMPLING PERIOD).
B—RELAY TIME SWITCH.
C—ELECTRIC MOTOR DRIVE.
D—PUMP FOR DRAWING AIR THROUGH SAMPLING HEAD.
E—MODIFIED THERMAL PRECIPITATOR SAMPLING HEAD.

Fig. 7.—Prototype equipment for automatic dust sampling.

have been adapted, and to some extent developed, for swing-frame grinding machines of the suspended or portable type. The device developed by the Association for swing-frame grinders is illustrated in Fig. 5, and in Fig. 6b, a unit fitted with this form of control is seen in operation, all airborne dust being brought under control within the specially designed cowling and extraction system. The B.S.C.R.A. system for dust control on swing-frame grinders, upon which development work is now in the final stage, will not only be applicable to new grinding machines, but also to existing units in use in the industry. The device, which is the subject of a Patent Application, is to be adopted by all the leading manufacturers of swing-frame grinding machines, with whom the Association has been in close contact throughout, and from whom valuable assistance has been given in the form of the loan of machines of varying types and sizes for experimental purposes.

Automatic Sampling of Atmospheric Dust

As a further part of the Association's programme of research into factors influencing working conditions, a programme sponsored by the British Steel Founders' Association and its Industrial Health Committee, a preliminary study has been made of dust concentrations in steel foundry atmospheres. Arising from this work, the need was demonstrated for the availability of an instrument capable of sampling atmospheric dust automatically over extended periods of time.

After consideration of the various principles employed in the sampling of atmospheric dust, it was concluded that thermal precipitation not only provided a sampling

efficiency of a high order, but also the most convenient method for the purpose in mind. With the advice and the facilities made available by Dr. P. F. Holt, of the University of Reading, modifications were made to the sampling head of a standard thermal precipitator dust sampler, so as to permit the glass cover slips, upon which the dust sample is normally collected, to be turned automatically through a small angle at predetermined intervals of time. In addition to this mechanical rotation of the sampling slips, a suction pump was devised to replace the orthodox water aspirator employed with the standard instrument. Means were also provided for varying the time interval during which individual samples could be taken, and for investigational purposes provision was also made for varying the rate of air flow through the head. Lastly, the batteries used to provide the current for heating the wire in the standard instrument have been replaced by an A.C. supply, so that the whole instrument is now electrically operated.

Fig. 7 illustrates the prototype equipment built upon this basis. A standard thermal precipitator head has been employed, two ratchet wheels being fitted to the outer ends of the sampling plugs. These ratchet wheels are engaged by solenoid-operated pawls, the solenoid being energised at predetermined intervals by an electrical pulse generator. In order to provide the required flow of air for the sampling head, an electrically-driven double-reciprocating pump has been constructed, this being encased as shown in the illustration by a Perspex cover. The rate of air flow may be adjusted by selecting a suitable gear ratio from the motor drive, the precise volume of air sampled in any given time being determined from the number of strokes on the reciprocating pump, recorded by a Veeder counter. The electrical supply to the whole instrument is controlled by a relay time switch intended to permit the instrument being switched on and off automatically at the beginning and end of each sampling period.

Radiographic Exposure Calculator

During the current year, the Association has designed and marketed an exposure calculator for use in conjunction with the various radioactive gamma ray sources now widely employed in industry for radiographic purposes. The current model performs all the exposure calculations necessary when using cobalt 60, iridium 192, or radon, permitting either exposure times or source-to-film distances to be rapidly computed for any given

Continued on page 191.

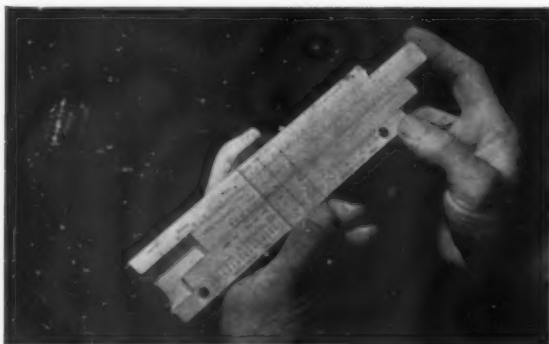


Fig. 8.—B.S.C.R.A. radiographic exposure calculator.

B.N.F.M.R.A. Service to Industry

By B. Fullman,* B.Sc., F.R.I.C., F.I.M., and E. C. Mantle,† M.Sc., A.I.M.

In previous years, articles on the British Non-Ferrous Metals Research Association have discussed mainly the research work in progress in the Association's laboratories. It is intended to strike a different note in this article and to deal with some of the other services the Association provides.

IT is not always realised that besides acting as a centre for co-operative research work for the non-ferrous metals industry, the British Non-Ferrous Metals Research Association provides its 600 member firms in this country and throughout the Commonwealth with a comprehensive technical service covering all aspects of the production and applications of non-ferrous metals, with the exception of routine testing. It includes a confidential consulting service, an information service, library facilities, the training of personnel, and holding a watching brief in many matters affecting the interests of members.

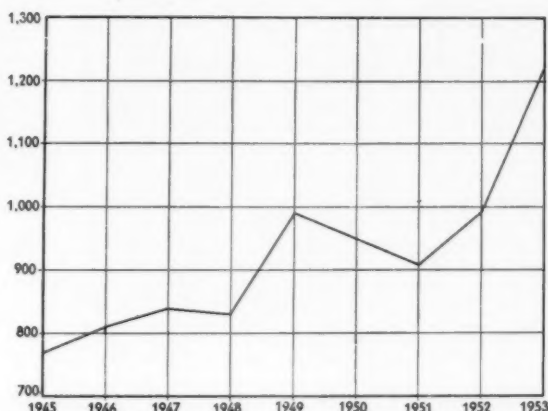
The Research Association is divided internally into three distinct departments:

- (1) Research
- (2) Liaison
- (3) Information and Library.

This article deals with the latter two departments.

The main function of a Research Association must be to conduct co-operative research for the industry it serves, and the Research Department is therefore by far the largest of the three. About 70% of the total income of £130,000 is spent directly on the research programme. Part of the income is derived from research contracts sponsored mainly by Government Departments, and, if this source of income is excluded, the proportion of the remainder (*i.e.*, that derived from members' subscriptions and normal Government grant) spent on Liaison and Information services is about 40%. This is divided between the Liaison and Information Departments in the ratio of about 2 : 1.

The Liaison Department and the Information Department are both concerned with the application of technical knowledge in industry. The Liaison Department, or to give it its full title, the Liaison and Technical Service Department, bridges the gap between the research workers and the member firms in the application of the results of the Association's researches. It also provides a confidential consulting service for members. The Information Department and Library has the function of providing the Association's own staff, member firms and Government Departments with any available recorded or other information in the non-ferrous metals field. Even though their functions are somewhat complementary the two departments are run quite separately. This is partly because the staff needed by the two departments is distinctly different in training and outlook. The Information Department is staffed by graduates who, in addition to their scientific qualifications, can read and translate technical literature in foreign languages. The work of the Liaison department, however, necessitates staff with considerable industrial



Liaison Department major technical enquiries 1945-53.

experience, who can appreciate the difficulties of industry, and have the necessary industrial "know-how" to present the answer to the problems in the correct perspective. Nevertheless, the Liaison Department in handling its enquiries frequently has recourse to the Information staff for advice on available knowledge, and a considerable portion of the time of the Information staff is spent in these joint discussions. Co-operation between the two departments is very close.

Technical Enquiry Service

One function of the Liaison Department is to provide member firms with a technical enquiry service, through which they are able to consult the Association about their day-to-day problems of a metallurgical nature. The success of this service, which is available to all member firms without extra charge, and to Government Departments, is apparent from the increasing use made of it year by year. It covers almost all aspects of members' technical requirements with the exception of routine analysis and testing. The enquiries are handled entirely on a confidential basis, and there is no disclosure to third parties. It is felt that the success of the service is due in no small measure to this fact, and over the years members have responded to this privacy by discussing their problems with us with great frankness.

The enquiries handled by the Liaison Department are the kind where practical "know-how" and experience of the industry are required, and a total of over 1,200 major problems was handled in 1953. These are in addition to the still larger number of enquiries which can be satisfied by reference to existing recorded knowledge and which are normally handled by the Information Department. Technical enquiries are received by post, over the telephone or through personal

* Chief Officer, B.N.F. Information Dept. and Library.

† Chief Officer, B.N.F. Liaison and Technical Service Dept.

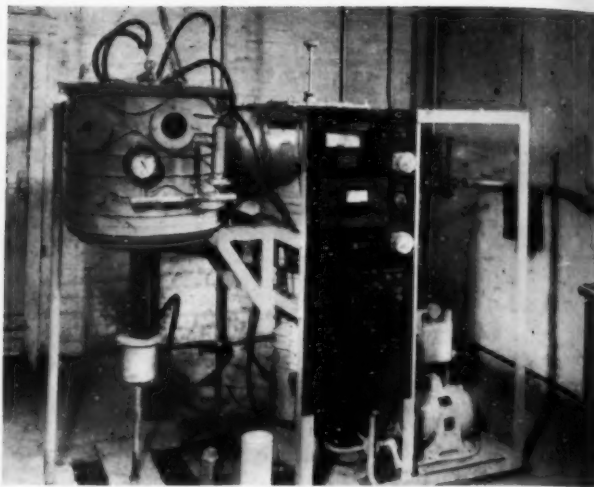


Part of the pilot scale "model" plating lines, demonstrating the best features of bright nickel plating practice.

contacts. Those handled by the Liaison Department include production difficulties, advice about applications of non-ferrous metals, the examination of service failures, and requests for information about, or for assistance with, new developments. Some of the enquiries develop into quite extensive investigations—one example being the work published recently on the occurrence of pinhole porosity in brass castings.* An investigation on this scale, however, is not usually undertaken as a technical enquiry unless it is obvious that the problem is of interest to a number of members.

The Liaison Department is staffed by a team of eight, which includes an expert on metal finishing and an engineer, as well as metallurgists each specialising in different branches of the industry. This team has the responsibility of handling technical enquiries and of maintaining contact between the Research Association and its member firms. This is additional to the close contact which always exists between member firms and individuals on the research staff who are working on a problem in which they are specially interested. In answering the varied enquiries received, the research staff are freely consulted for expert advice, and indeed, where the problem is closely related to the research work, the investigator concerned often handles the enquiry. In most cases, however, the onus of collecting and sifting the information, of progressing any experimental work needed, and of formulating the final reply to the enquiry rests with the Liaison Department. While it is, of course, important that the research staff should have opportunity for contact with industry, it is equally important that they should not have to devote too much of their attention to the day to day handling of technical enquiries, for either the progress of the research work would be hindered or else delay in answering enquiries would make the service next to valueless.

* N. B. Rutherford, *Foundry Trade Journal*, July 1, 1964, 97, 13.



Furnace for making alloys and casting ingots in vacuum.

Many of the enquiries received call for practical examinations, and various sections of the Research Department give much practical help with analyses, metallographic work and other testing and experimental work, for although routine testing is not carried out, analyses or other tests required for the solution of a specific problem are readily undertaken. Frequently an enquiry can only be answered after a visit to the member's plant or the site of the installation, and the Liaison Staff made 177 visits for this purpose in 1953.

Undoubtedly, this service is a great attraction to the smaller and medium size firms which have limited technical resources of their own. It is also invaluable to the large number of engineering firms and other users of non-ferrous metals among the Association's membership who cannot themselves maintain the specialists in non-ferrous metals available to them through this consulting service. Such a service can help very materially in raising the technical efficiency of industry. Concentration on services of this kind instead of longer term research work has often been advocated as a means of obtaining quick dividends in the shape of increased support for a Research Association. However, this could never be more than a short term measure, and it must always be borne in mind that a technical enquiry service depends on the application of existing knowledge supplemented from time to time by small *ad hoc* investigations. In the long run it is from research work of a more basic character that new developments and true progress must arise.

Application of Research Results

At present, the Research Association has over 40 major researches in progress, covering the whole non-ferrous field from extraction metallurgy to electroplating.*

Considerable thought has been given to the method of disseminating the results of the researches. Thus, in 1953, 49 confidential reports were released to members. Many of the reports are of interest to only one or two sections of the industry, and it would therefore

* For details see the *B.N.F.M.R.A. Thirty-Fourth Annual Report*, 1954 (available on request); and *METALLURGIA*, 1953, 48, 183 and earlier.



A section of the library.

obviously be pointless to send copies of every report automatically to all members. The ideal is for Liaison staff to make frequent visits to all firms to discuss the work and its bearing on the members' activities. With such a large membership, this is quite impracticable. Although in 1953 the Liaison Staff made about 290 visits to members, this still does not cover the whole membership every year. To overcome this difficulty a monthly journal, known as the *B.N.F. Review*, was instituted some years ago. The *B.N.F. Review* is a confidential journal sent to members and Government Departments only. It surveys, in the form of short articles, the research reports released during the previous few weeks, and the progress of some of the researches. Its aim is to give the essential details about the object of the research work and the practical importance of the results with the minimum detail of experimental work. Members can quickly see what is likely to be of value to their own firms and can then request copies of the full research reports for further study. This they do on a large scale, sometimes asking for as many as six copies of a report for circulation.

Development Work

Many of the researches being undertaken in the laboratories are of a type where data are being collected about the properties of materials, or the effects of variations in composition or of impurities, and the results of such work can be applied by many members directly, little assistance from the Research Association being required. A recent example is an investigation on the influence of zinc on the properties of the aluminium casting alloy B.S. 1490-LM4, which has culminated in the drafting of a new specification allowing greater latitude for zinc. In other cases, however, it is found that further development work or industrial trials are needed before the results of a research can be placed before industry in the form of firm, practical recommendations. Development work of this kind is another function of the Liaison Department, which frequently and successfully collaborates with members' own technical staff in organising industrial development work. Papers describing the results of co-operation of this nature have



Machine developed by the B.N.F.M.R.A. for high temperature fatigue and corrosion-fatigue testing.

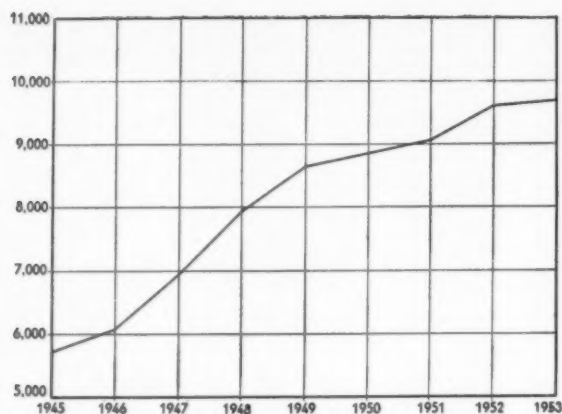
been published from time to time in the technical Press,* though usually the recommendations are made available to members in the form of confidential development reports. Examples include development work on the production of gunmetal and aluminium-magnesium alloy castings; the use of feeder sleeves in non-ferrous foundries; and increasing the efficiency in the use of zinc in the hot dip galvanising industry. Currently, the Liaison Department is collaborating with members in works trials of lubricants for drawing copper tubes; in field trials of magnesium anodes and other protective measures for prolonging the life of galvanised water tanks in particularly aggressive waters; and in the examination of paint systems for the protection of structural steelwork in galvanising shops and over pickling tanks. Work is also in hand to develop the results of a recently completed research on an alternative method to dosing with salts for controlling the gas contents of melts for light alloy die castings.

Conditional Aid Funds

In common with many similar organisations, the Association received a grant from Conditional Aid Funds which has enabled it to extend, in certain directions, the advisory services it already provides for members. Extra staff has been taken on to enable a survey to be made, with the full concurrence of the electroplating organisations in the country, of the technical efficiency of the plating industry. A "model" demonstration bright nickel plating line has also been set up in the Association's laboratories embodying all good principles of plating practice.

This new service is open to members and non-members alike. Already surveys have been made of about 20 firms, each of which has received a confidential report

* See, e.g., L. Buckley and E. C. Mantle, "Pressure-Tight Gunmetal Castings: Application of Research Results to Production Technique," *Foundry Trade Journal*, 1961, 91, 727.



External (postal) library loans 1945-53.

making recommendations for improving practice where appropriate. Acting on such reports, some firms are completely re-planning their plating shops with the assistance of the Association's staff. Eventually, a report will be published giving the general conclusions of this survey. All possible precautions will, of course, be taken to avoid identifying the firms who have collaborated.

Similar work is being undertaken with the manufacturers of lead pipe. The Association also has an arrangement with the Association of Bronze and Brass Founders to train an advisor in shell moulding, and to give advice on this subject through the advisory scheme being organised by the A.B.B.F. with Conditional Aid Funds.

Information Department and Library

In the Information Department there is a staff of four science graduates who in addition to their scientific qualifications can read and translate technical literature in German, Russian and French. The Library is managed by a chartered librarian with three assistants.

The Library

We hold the view that an information service must be based on a first-class library, adequately stocked and competently staffed. Currently, the library holds about 5,000 books and bound volumes, and takes over 250 periodicals in a variety of languages. A special feature is a unique collection of over 30,000 separates (reprints, preprints, photocopies, manuscripts, translations, etc.), the existence of which obviously promotes mobility and convenience of handling and, incidentally, greatly economises the cost of postal loans. Author and subject indexes are maintained. A large number of British and some foreign patent specifications are held, as well as standard specifications issued by various bodies. Trade literature (*i.e.*, catalogues and leaflets describing individual products of various firms) is also available.

The library stock, covering non-ferrous metallurgy as well as essential material in related fields, is kept up to date by prompt acquisition of new publications. Some 1,500 new items (books and pamphlets) are added annually. If the demand necessitates it, more than one copy is obtained.

Of the periodicals held, some are bound, some are kept unbound in individual parts, and some are discarded at

convenient intervals. The books are also "weeded," obsolescent material being relegated to a reserve store or discarded. The deliberate intention is to keep the stock at a workable level of essential material, and not to dilute it with a large volume of inessentials: in short, to maintain a library, not a museum. This, incidentally, permits of keeping the stock under control with economy in staff and space. The main demand is for the fairly modern material, and the occasional requirements of older material can be satisfied from various other establishments, though very long runs of essential periodicals are available. The whole of the stock, except for abstract journals and a few very expensive works of reference, is freely available for loan to members and Government Departments. In addition, requests for literature not in stock can often be satisfied with the assistance of numerous other libraries with whom we have friendly relations, or by referring the enquirer to another establishment from which he can borrow directly. The library staff has considerable experience in and facilities for locating literature. Incidentally, we lend to and borrow or arrange loans from a considerable number of other Research Associations.

There is a special card index (now numbering several thousand cards) of trade names and information on branded materials and processes, and kindred matters. It supplements the information of this type available in various books. This index is a valuable tool in frequent daily use, in some instances providing a complete history of materials which have emerged in recent years.

The library is heavily drawn upon by the Association's staff, by members, and by Government Departments. It is an outliner of the National Central Library. In 1953, it was used by 51% of the members (often by more than one individual in a works) and altogether to all external borrowers over 9,700 items of literature were lent by post, while a larger number were provided internally to Association staff. Our star turn is a member company which in one year borrowed (and returned promptly) over 550 items. Loans are made with the minimum of formality against requests by post, by telephone or personally. No postal charges are made. Members are encouraged to visit the library for their own reading if they wish.

The Library offers assistance to the overseas members of the Association in the various countries of the Commonwealth, by providing microfilm or other photocopies of literature difficult of acquisition, sometimes by advice on locations of the literature in the enquirer's own country, and sometimes by direct loans. There is now a brisk correspondence with Commonwealth members.

Information Services

All the literature acquired is scrutinised by the Information Officers, and papers, books or other items of importance are promptly recorded in the monthly *B.N.F.M.R.A. Bulletin* in the form of short notes. The *Bulletin*, which covers the world's non-ferrous metallurgical literature, is deliberately selective, only items of practical utility or theoretical importance being noted, so that references to the cream of the literature can be provided in small compass. Thus in 1953 reference was made to over 2,800 papers and books, as well as to 700 British patent specifications, the latter being presented in the form of the title suitably (and sometimes considerably) expanded to indicate the contents. The *Bulletin* is issued free to all members and Government

Departments, as many copies being available in each instance as are required. Annual author and subject indexes are supplied. By means of a form enclosed in each *Bulletin*, members are encouraged to borrow any item of literature in which their interest has been aroused. "Easibind" binders for the *Bulletin* are available on sale from the makers, and the considerable number sold annually indicates that many members keep the *Bulletin* regularly on file.

Into the Information Department comes a constant stream of enquiries, ranging over a wide field—properties of materials, compositions, sources of supply, specifications and other topics too numerous to mention—in short, anything that the enquirer wants to know. In fact, our experience is that members are ready to try anything at least once! The enquiries may originate internally or externally, by letter or telephone. Among the commonest enquiries is the identification and description of materials from trade names or foreign specifications. Latterly, these have assumed a special significance, as in many cases the enquirers are obviously being asked by overseas customers to provide products hitherto obtained from foreign countries.

If our own resources do not suffice in dealing with enquiries, telephone calls are made to other establishments or enquiries are made abroad. Members make extensive use of the information service both by telephone and letter, telephone calls from the provinces being quite common. Enquiries come from every kind of firm, from the largest to the smallest. When new information emerges from an enquiry a record is made, but otherwise the staff are too busy to keep permanent records of every enquiry. Apart from the regular flow of enquiries by letter, it may be mentioned that in May, 1954, a check was made of telephone enquiries to the Information Department. In that month, 70 enquiries for information were made by telephone alone: the enquirers were mainly member companies, but in addition there were Government Departments, technical societies, other Research Associations and a foreign embassy. In the same month the Library received 120 telephone requests for the loan of specific items of literature.

The Information Department makes searches of the literature on topics of interest to members, and assists the Association's research staff in literature surveys when new researches are undertaken.

Translations

As indicated above, the Information staff are competent to deal with foreign literature. Nevertheless, in view of the labour involved, a foreign paper is carefully considered before a full translation is undertaken: there is no point in translating poor papers from one language into another. Some 30 papers are translated each year, and in addition help is constantly given to the research and liaison staff by immediate verbal discussion of foreign papers in which they are interested. In case of need, competent external technical translators are employed for languages such as Japanese or the Scandinavian languages which are not available internally. Last, but not least, it is a pleasure to mention that a number of member companies, who prepare translations of their own, are good enough to provide copies to the Library for loan to other members.

Other Services

An organisation such as the B.N.F.M.R.A. representing the whole of the non-ferrous metals industry has a duty in ensuring that high standards are maintained in the quality of products from the industry, and the Association plays an important part in the formulation of many British Standards. It represents the interests of its member firms on no less than 81 B.S.I. Committees. It also provides its member firms with facilities for familiarising their employees with specialised techniques; for instance, many send their staff for training in the use of the spectrograph or of chemical methods for the analysis of non-ferrous alloys, or for instruction in metallographic techniques.

British Steel Castings Research Association

Continued from page 186

radiographic problem, and is, as far as is known, the first to be produced for use with the artificially-prepared radioactive isotopes. A second model, now in course of preparation, has additional scales to cover the more recently available isotopes, caesium 137 and thulium 170. Both calculators are based upon experimental data made available to the Association by the Armament Research Establishment of the Ministry of Supply, Woolwich, and, as illustrated in Fig. 8, are in the form of plastic, pocket-size slide rules, having two sliding scales, the relative setting of which correlates the six variables, source strength, source-to-film distance, steel thickness, exposure time, film density and film speed. The original calculator includes scales for calculation of radon and iridium decay, as well as one which gives the thickness of steel which, for the purpose of setting the rule, may be employed when examining materials other than steel.

Submarine Cable Merger

BRITISH INSULATED CALLENDER'S (SUBMARINE CABLES), LTD.—with an authorised capital of £250,000—has been formed by British Insulated Callender's Cables, Ltd., and W. T. Glover & Co., Ltd., to specialise in the design and manufacture of submarine power cables. The Registered Office of the Company is Norfolk House, Norfolk Street, London, W.C.2, and the Works are at Trafford Park, Manchester. During most of 1955, the Company will be occupied with the manufacture of approximately 77 miles of 138 kV 0.35 sq. in. gas-filled submarine power cable for the British Columbia Electric Co., Ltd., of Canada, to the order received by British Insulated Callender's Cables, Ltd. Mr. W. H. McFadzean is Chairman of the Company and the other Directors are Messrs. C. O. Boyse, K. S. Brazier (Works Manager), E. L. Davey (Chief Engineer), R. M. Fairfield (General Manager), W. C. Handley, D. T. Hollingsworth, and H. J. Stone, M.C. The Secretary is Mr. F. V. Thompson.

Lorrain's British Agents

THOS. STOREY (ENGINEERS), LTD., of Victoria Street, London, have been appointed sole agents in the British Isles for Lorrain Equipment—the products of the Thew Shovel Company of Lorraine, Ohio, U.S.A. Storeys will be selling agents and will provide a spare parts repair service for the equipment, which includes a range of mobile cranes from four tons to sixty tons, and excavators up to two and a half cubic yards.

NEWS AND ANNOUNCEMENTS

Symposium on Powder Metallurgy

A SYMPOSIUM on Powder Metallurgy, organised by The Iron and Steel Institute in association with The Institute of Metals, will take place in The Hoare Memorial Hall, Church House, Westminster, London, S.W.1 (entrance in Great Smith Street), on Wednesday and Thursday, 1st and 2nd December, 1954.

The papers cover both ferrous and non-ferrous aspects of powder metallurgy, and the Symposium is open to all interested in this subject, whether members of The Iron and Steel Institute or The Institute of Metals or not. A small Exhibition of powder-metallurgy components, staged in Committee Room No. 6 in Church House during the days of the Symposium, will be open from 9.30 a.m. on both days, and will close at 7.45 p.m. on December 1st, and 5 p.m. on December 2nd. On the evening of Wednesday, December 1st, a Reception will be held in the Restaurant, Church House, from 5.45 p.m. to 7.45 p.m. when the Presidents of The Iron and Steel Institute and The Institute of Metals, The Hon. R. G. Lyttelton and Dr. S. F. Dorey, C.B.E., F.R.S., will receive the participants.

The fifty papers contributed to the Symposium have been divided into four groups and each group will be presented by the rapporteur named below.

Wednesday Morning Session (9.30 a.m.).

GROUP I PAPERS—MANUFACTURE, PROPERTIES AND TESTING OF POWDERS.

Rapporteur: DR. A. L. NORTHCOTT.

- "Metal Powders for Engineering Purposes—A Review," by W. D. JONES.
- "The Grinding of Metal Powders," by G. F. HUTTIG and H. SALES.
- "The Production and Fabrication of Tantalum Powder," by R. TITTERINGTON and A. G. SIMPSON.
- "The Powder Metallurgy of Zirconium," by F. G. COX and G. L. MILLER.
- "Powders for Magnetic Applications," by G. R. POLGREEN.
- "Recent Developments in Testing Metal Powders," by G. R. BELL.
- "Application of Particle Size Analysis to the Quality Control of Metal Powders," by V. T. MORGAN.
- "Determination of the Gas Contents of Materials of Powder Metallurgy Practice," by H. A. SLOMAN.
- "Factors Influencing the Reactivity of Solids, with Particular Reference to Metals," by J. A. HEDVALL.

Wednesday Afternoon Session (2.15 p.m.).

GROUP II PAPERS—PRINCIPLES AND CONTROL OF COMPACTING AND SINTERING.

Rapporteur: DR. A. BLAINEY.

- "The Mechanism of Infiltration," by P. SCHWARZKOPF.
- "The Sintering Mechanism of Pure Metals, Including 'Activated Sintering,'" by M. EUDIER.
- "Variation of Thermo-Electric Force during Sintering," by G. RITZAU.
- "The Designation of Powders and Sintered Materials by Means of the Properties of the Pore Volume," by K. TORKAR and G. F. HUTTIG.
- "Pore Size Distribution and Permeability of Porous Metal Materials," by P. R. MARSHALL.
- "Filter Elements by Powder Metallurgy. Part 1. The Properties of Spherical Packings. Part 2. The Properties of Filter Elements from Spherical Powder," by V. T. MORGAN.
- "The Relationships between the Properties of Iron Powders and Powder Compacts," by F. V. LENEL, H. D. AMBS and E. O. LOMERSON.
- "Pressing Characteristics of Air-Atomised Copper Powder," by A. DUFFIELD and P. GROOTENHUIS.
- "Grain Growth during Sintering," by H. H. HAUSNER.

- "The Hot Compacting of Metal Powders," by J. WILLIAMS.
- "The Hot Pressing of Ceramics," by P. MURRAY.
- "The Continuous Compacting of Metal Powders," by P. E. EVANS and G. C. SMITH.
- "Effect of Small Boron Contents on the Properties of Sintered Bodies Prepared by Vacuum Sintering," by F. FREHN and W. HOTOP.
- "Sintering Furnace Atmospheres," by L. D. BROWNLEE, R. EDWARDS and T. RAINE.

Thursday Morning Session (9.30 a.m.).

GROUP III PAPERS—MANUFACTURE AND PROPERTIES OF STRUCTURAL ENGINEERING COMPONENTS.

Rapporteur: DR. P. R. MARSHALL.

- "Some Developments in Sintered Structural Parts," by C. J. LEADBEATER.
- "Experiments on the Production of High-Strength Material and Parts by Powder Metallurgy," by L. HARRISON and S. MARTON.
- "Sintered Nickel Steel and Notes on Other Sintered Alloys," by S. C. WILSDON and P. J. RIDOUT.
- "Solid Stainless Steel Compacts from 18/8 Austenitic Powders," by B. SUGARMAN.
- "Porous Stainless Steel. Parts I-V," by D. A. OLIVER, S. C. WILSDON, P. R. MARSHALL, B. SUGARMAN, G. COLLINS and C. T. J. JESSOP.
- "The Porosity and Air-Permeability of Sintered Iron and Iron-Copper," by C. J. LEADBEATER and S. TURNER.
- "Low-Expansion Nickel-Iron Alloys Prepared by Powder Metallurgy," by V. THOMAS and D. J. JONES.
- "Application of Powder Metallurgy to the Production of High-Permeability Magnetic Alloy Strip," by E. V. WALKER, D. K. WORN and R. E. S. WALTERS.
- "Fatigue Properties of Sintered Copper Compacts," by O. J. DUNMORE and G. C. SMITH.
- "Production of Sintered Copper-Lead Bearing Materials," by W. E. DUCKWORTH.
- "Properties and Testing of Sintered Copper-Lead Bearing Materials," by P. G. FORRESTER and W. E. DUCKWORTH.
- "Fluon-Impregnated Self-Lubricating Bearing Materials," by A. BLAINEY.
- "Sintered Aluminium Powder," by R. IRMANN.
- "Preparation of High-Modulus Aluminium Alloys by Powder Metallurgy," by N. F. MACDONALD and C. E. RANSLEY.
- "Powder Metallurgy of Magnesium," by D. J. BROWN.

Thursday Afternoon Session (2 p.m.).

GROUP IV PAPERS—POWDER METALLURGY OF HIGH-MELTING-POINT MATERIALS.

Rapporteur: MR. B. E. BERRY.

- "Developments in High Density Alloys," by E. C. GREEN, D. J. JONES and W. R. PITKIN.
- "The High Temperature Strength of Some Co-Ni-Fe-Cr Base Materials made by Powder Metallurgy," by G. T. HARRIS and H. C. CHILD.
- "Preparation and Properties of Titanium Alloys Prepared by Sintering," by D. A. ROBINS, W. R. PITKIN and I. JENKINS.
- "Sintered Titanium Carbide Alloys," by E. M. TRENT and A. CARTER.
- "The Testing of Ceramels, with Particular Reference to a Simple Titanium-Carbide/Cobalt Material," by T. W. PENRICE and D. H. SHUTE.
- "The Creep Strength of Titanium-Carbide-Base Materials," by G. T. HARRIS, H. C. CHILD and J. F. HOWARD.
- "Silicides of the Transition Metals of the 4th, 5th and 6th Groups of the Periodic Table," by R. KIEFFER and F. BENESOVSKY.
- "Effect of Carbon Content on the Properties of Tungsten-Carbide/Cobalt Hard Metals," by L. D. BROWNLEE, R. EDWARDS and T. RAINE.
- "Chromium Carbide in Hard Metal Alloys," by J. HINNBERG and O. RUDIGER.
- "Metal-Ceramic Bodies," by A. E. S. WHITE, F. K. EARP, T. H. BLAKELEY and J. WALKER.

- "Development of Metal-Ceramics from Metal-Oxide Systems," by J. R. BAXTER and A. L. ROBERTS.
- "The Rupture Strength of Some Metal Bonded Refractory Oxides," by G. T. HARRIS and H. C. CHILD.

Further particulars can be obtained from the Secretary of the Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1.

Institute of Welding

Autumn Meeting

The programme for the Autumn Meeting of the Institute of Welding, which is to be held in London from 27th to 29th October, 1954, opens with the Annual Dinner at the Park Lane Hotel, Piccadilly, on Wednesday, October 27th. Technical sessions at the Institution of Civil Engineers, Great George Street, S.W.1, will open on Thursday morning with the Presidential Address by Mr. R. G. Braithwaite. The following papers will be presented for discussion:—

Thursday Morning Session.

- "A New Process of Stud Welding," by W. P. VAN DEN BLINK
E. H. ETTEMA and P. C. VAN DER WILLIGEN.

Thursday Afternoon Session.

- "The Automatic Argon Arc Welding of Low Alloy Steel Sheet," by F. J. WILKINSON.
- "The Twin Argon Welding Process," by J. A. DONELAN.

Friday Morning Session.

- "Vanadium as Replacement for Molybdenum in Low Alloy Steels," by C. L. M. COTTRELL and B. J. BRADSTREET.
- "Weldability of a B-Mo Steel Related to the Properties of the Heat-Affected Zone," by C. L. M. COTTRELL.
- "Weldability of Mn-Mo Steel Related to the Properties of the Heat-Affected Zone," by C. L. M. COTTRELL.

Further details may be had on application to the Secretary, The Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1.

Institute of Metals

General Meeting

FOR the benefit of members of the Institute of Metals who were unable to take part in its 1954 Autumn Meeting in Switzerland, a special General Meeting for the discussion of scientific papers will be held at 4, Grosvenor Gardens, London, S.W.1, on Thursday and Friday, 25th and 26th November, 1954. Non-members of the Institute will be welcome at this meeting, for which tickets are not required. A central theme has been chosen for each of the three sessions, and a list of the papers to be discussed is presented below. The details in parenthesis refer to the issue of the *Journal of the Institute of Metals* in which the particular paper was published.

Thursday Afternoon Session (2-30 p.m.).

THE CONSTITUTION OF TITANIUM ALLOYS.

- "The Structure of Titanium-Tin Alloys in the Range 0-25 At.-% Tin," by H. W. WORNER (Serial No. 1473; July, 1953).
- "The Re-investigation of a Nickel-Titanium Alloy and Observations on $\beta/(\alpha+\beta)$ Boundaries in Titanium Systems," by A. D. MCQUILLAN (Serial No. 1494; September, 1953).
- "The Free-Energy Diagram of the System Titanium-Oxygen," by O. KUBASCHOWSKI and W. A. DENCH (Serial No. 1500; October, 1953).

- "The Structure of Titanium-Silver Alloys in the Range 0-30 At.-% Silver," by H. W. WORNER (Serial No. 1515; January, 1954).

- "A Redetermination and Interpretation of the Titanium-Rich Region of the Titanium-Chromium System," by (Mrs.) M. K. MCQUILLAN (Serial No. 1535; May, 1954).

- "Methods for Determining the Liquidus Points of Titanium-Rich Alloys," by W. HUME-ROTHERY and D. M. POOLE (Serial No. 1545; June, 1954).

- "Note on the Constitution of the Titanium-Gold System in the Region 0-6 At.-% Gold," by (Mrs.) M. K. MCQUILLAN (Serial No. 1548; July, 1954).

- "The Constitution of the Titanium-Rich Alloys of Titanium, Iron and Oxygen," by N. P. ALLEN, T. H. SCHOFIELD and (Mrs.) B. MELLISH (Serial No. 1551; July, 1954).

Friday Morning Session (10 a.m.).

PREFERRED ORIENTATION.

- "A Theoretical Investigation of the Deformation Textures of Titanium," by D. N. WILLIAMS and D. S. EPPELSHEIMER (Serial No. 1476; July, 1953).

- "A Study of Preferred Orientation in Extruded, Drawn, and Annealed Copper," by P. G. BASTIEN and J. POKORNY (Serial No. 1553; August, 1954).

- "Preferred Orientation in Rolled Uranium Sheet," by J. ADAM and J. STEPHENSON (Serial No. 1555; August, 1954).

Friday Afternoon Session (2-30 p.m.).

CORROSION AND STAINING OF ALUMINIUM ALLOYS.

- "The Influence of Extrusion Direction on the Corrosion and Stress-Corrosion of Aluminium-Copper-Magnesium Alloys," by E. A. G. LIDDIARD and WINIFRED A. BELL (Serial No. 1534; May, 1954).

- "Staining of Clad Aluminium Alloy Sheets During Salt-Bath Heat-Treatment," by E. C. WILLIAMS and H. J. G. CHALLIS (Serial No. 1541; June, 1954).

Iron and Steel Institute

Autumn Meeting

THE Autumn General Meeting of the Iron and Steel Institute will be held on Wednesday and Thursday, 17th and 18th November, 1954, at the Offices of the Institute, 4, Grosvenor Gardens, London, S.W.1. The papers to be presented for discussion are listed below, the issue of the *Journal of the Iron and Steel Institute* in which they were published being given in parenthesis.

Wednesday Morning Session (10-15 a.m.).

- "The Future of Steel Melting," by M. W. THRING (April, 1954).
- "The Problem of Rupture of the Billet in the Continuous Casting of Steel," by J. SAVAGE and W. H. PRITCHARD (November, 1954).

Wednesday Afternoon Session (2-30 p.m.).

- "The Effect of Cold Work on the Gamma-Alpha Transformation in Some Iron-Nickel-Chromium Alloys," by B. CINA (August, 1954).
- "A Critical Investigation into the Ageing of Mild Steel Strip after Temper Rolling," by B. JONES and R. A. OWEN-BARNETT (June, 1954).
- "Accelerated Strain-Ageing of Mild Steel," by B. B. HUNDY (September, 1954).
- "Elimination of Stretcher Strains in Mild-Steel Pressings," by B. B. HUNDY (October, 1954).
- "Yield-Stress Strain Curves and Values of Mean Yield Stress of Some Commonly Rolled Materials," by R. B. SIMS (August, 1954).

Thursday Morning Session (10 a.m.).

- "An Investigation of Reheating Furnace Design and Performance," by F. A. GRAY and S. H. BROOKS (November, 1954).
- "Internal Temperature Distribution in the Cooling and Reheating of Steel Ingots," by R. J. SARGANT and M. R. SLACK (August, 1954).

"The Length of Oil and Gas Flames—Extension of Free Flame Relationships to Practical Conditions," by A. L. CUDE (March, 1954).

"Measurement and Influence of Preheat in the Open-Hearth Furnace," by W. P. CASHMORE (October, 1954).

Thursday Afternoon Session (2-30 p.m.).

"Fatigue Tests on Rolled Alloy Steels Made in Electric and Open-Hearth Furnaces," by P. H. FRITH (Special Report No. 50).

Chemical and Petroleum Engineering Exhibition

ARRANGEMENTS have now been completed to hold for the first time in the United Kingdom a joint exhibition of chemical plant and petroleum equipment. This exhibition will be known as The Chemical and Petroleum Engineering Exhibition and will take place in the Grand Hall, Olympia, London, in June, 1958; it will be organised by F. W. Bridges and Sons Ltd., and sponsored jointly by the British Chemical Plant Manufacturers' Association and the Council of British Manufacturers of Petroleum Equipment.

Epoxide Resins Patent Agreement

AN agreement has been reached between Aero Research Ltd. and Shell Chemicals Ltd. covering, in the United Kingdom, the patents held by Ciba and Shell in the field of epoxide resins. This agreement will be of particular value to the paint industry, in that it will give freedom under both the Ciba and Shell patents to all purchasers of epoxide resins from either Company to sell or use these materials in the surface coating field. In the specialised fields of potting, casting, laminating and adhesives, similar freedom under the patents will be available to customers purchasing epoxide resins from either Company for their own use but not for resale in their original or modified form.

Dorman Long Subsidiaries

THE trading activities of Dorman, Long and Co. Ltd. have been taken over by three wholly-owned subsidiaries. Dorman Long (Bridge and Engineering) Ltd. has taken over the trading activities carried on at the Bridge and Constructional Works, Middlesbrough, at the London Constructional Works, and at the Bridge and Contracting Department, Luton. Dorman Long (Chemicals) Ltd. has taken over the trading activities concerned with coal by-products distillation carried on at Port Clarence. All the remaining direct trading activities are now the concern of Dorman Long (Steel) Ltd. The effect of these changes is that Dorman, Long and Co. Ltd. ceases to trade, but continues, as a holding company, to co-ordinate the general policy of the group including the three new subsidiary companies. Relations with customers and supplier will not be affected as the trading activities of the new companies are to continue under the same management.

Personal News

BRITISH DRIVER-HARRIS CO., LTD. announce the following appointments at their Cheadle Works: General Manager, MR. A. CLARK; Works Manager, MR. J. H. IRELAND, Assistant Works Manager, MR. J. L. COOPER; and Foundry Manager, MR. H. MCLEAVY.

MR. D. McDONALD, Chairman of the Executive Committee of the Board of Johnson Matthey & Co., Ltd.

since 1950, retired at the end of August after 44 years' service with the company, which he entered as a junior chemist in 1910. MR. McDONALD was presented with a cheque and a bound book of signatures of his colleagues and friends throughout the company.

MR. J. E. BAGGULEY, General Production Manager at the Distington Engineering Co. Ltd., has been appointed Works Manager of another United Steels Branch—The Yorkshire Engine Co., Ltd. MR. R. LANCASTER, Works Manager, has been appointed General Works Manager at Distington.

MR. C. STURDY, formerly Assistant Sales Manager, has been appointed Assistant Chief Engineer (Projects) of Davy and United Engineering Co., Ltd.

MR. W. A. HARTOP, Works Director of George Kent, Ltd., is spending two months in Canada, assisting the production organisation of Kent-Norlantic Ltd., Toronto, towards full operations. He is also investigating export prospects for Kent products.

MR. R. S. JONES has retired from his position as Manager of the Plant Sales Department of the British Thomson-Houston Co., Ltd., after forty-one years' service with B.T.H. He is succeeded by MR. R. M. GRANT, Assistant Manager of Plant Sales Department.

The Council of the Institute of Metals has elected MR. H. S. TASKER, a Fellow, in recognition of his distinguished services to the Institute. The total number of Fellows is limited to twelve.

MR. G. G. BUCKINGHAM has been appointed Manager of the Manchester office of Babcock & Wilcox, Ltd., in succession to the late Mr. F. W. Woodfield.

Warwick Production Co., Ltd. announce the appointment of MR. T. J. HARTNETT, formerly of the British Aluminium Co., Ltd., as their Technical Sales Representative for the London and South Eastern areas.

MR. C. G. TANGYE has been elected Chairman of Council of the British Internal Combustion Engine Research Association in succession to MR. H. N. G. ALLEN.

MR. L. G. BROADWAY has been appointed Managing Director of C. C. Wakefield & Co., Ltd. in succession to MR. A. LIMB, who has had to relinquish this office owing to ill-health. Mr. Limb will continue as a Director of the company. The position of Assistant Managing Director will be held by MR. W. F. LIST.

Obituary

We regret to record the deaths of the following:

MR. FREDERICK GRANT, M.C., Q.C., the Independent Chairman of the Executive Committee of the British Iron and Steel Federation, who died on Sunday, 19th September. Mr. Grant was appointed to the position about a year ago, in succession to the late Sir Andrew Duncan.

MR. H. G. YATES, Senior Designer of The Parsons and Marine Engineering Turbine Research and Development Association, who died suddenly at his home near Newcastle upon Tyne on Wednesday, September 15th, at the age of 46. Mr. Yates had held the post of Senior Designer from the inception of Pametrada in 1944, and much of the progress made in marine turbine design and practice during the last ten years may be traced to his influence.

MR. D. R. A. PISTOR, a Director of B.K.B. Electric Motors Ltd., and for nearly forty years Manager of the Hibbert Street Works of George Kent Ltd., who died suddenly on September 23rd while on holiday in Scotland.

RECENT DEVELOPMENTS

"Redux" in Film Form

THE Redux bonding process has now been used in some forty well-known aircraft, and service under flying conditions covers a period of more than ten years. This month, Aero Research Ltd., announce the introduction of the adhesive in a new form which should contribute towards greater ease and economy in use. It consists of the identical Redux liquid and powder, supplied as a film expressly, but not exclusively, for bonding metal skins to metal honeycombs to make the sandwich structures in which leading aircraft makers are now showing interest. Redux film, which is covered by specification D.T.D.775A, is supplied in rolls with protective covering, and has a storage life of at least six months.

For bonding panels to honeycombs, it is first consolidated on to the metal skin under heat and vacuum pressure, with a sheet of aluminium foil placed between the film and the rubber blanket to prevent sticking to the rubber. The heating cycle for this operation is 10 minutes at 145°C. After cooling, the aluminium foil is stripped off and a coating of Redux 120 applied by brush over the partially cured film. Redux 120 should also be applied to the edge of the honeycomb. The Redux 120 is dried at 80°C. for 30-60 minutes before assembling skins and honeycomb and curing the adhesive at 145°C. under vacuum pressure. The curing time depends on such factors as the thickness of the honeycomb, and may be assumed to be about 1 hour for a $\frac{1}{2}$ in. thick honeycomb core sandwich, heated one side only.

Tests to destruction at room temperature have shown the failing load on lap joint specimens cured under vacuum at 12 lb./sq.in. to be of the order of 4,100 lb./sq.in. (specimens: 20 s.w.g. D.T.D. 546, 1 in. wide and $\frac{1}{2}$ in. overlap, pickled to D.T.D.915 A for 1 hour at 60°C., and cured for 30 min. at 145°C.)

An important advantage of Redux film is that it ensures exact control of the proportions of powder and liquid in the bond, and this has resulted in improved strength at elevated temperatures.

Redux film can be used for normal metal-to-metal bonding processes, as for example in stringers to skins, and the curing cycle is 30 minutes at 145°C. It may be expected, however, that the main uses of the film will lie in the bonding of skins to honeycomb cores (for which purpose an adhesive is essential). In neither application is any priming of the metal surfaces required before application of the adhesive.

Aero Research Ltd., Duxford, Cambridge.

Prefired Ladle Liners

NOR long ago, The Morgan Crucible Company introduced the Salamander plumbago ladle liner as a means of obtaining a liner with a longer life than the conventional loam facings. There were also other advantages, including the abolition of the daily maintenance of the steel shells, and the fact that these one-piece liners could last up to 40 times longer than the "clay-daubed" type. Furthermore, they help to overcome the difficulties which have arisen since the institution of the new order prohibiting the use of open fires or braziers in foundries.



Results are now available of the sort of life to be expected from the plumbago liners, as many as 3,250 pours having been obtained with a 25-lb. ladle casting Meehanite iron. Ten 195-lb. ladles casting this metal averaged 1,500 pours, and 245-lb. ladles casting copper alloys gave figures of 1,000-1,500.

A modification of the original pattern introduced recently takes the form of a replaceable slag baffle shown in the illustration.

The Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W.11.

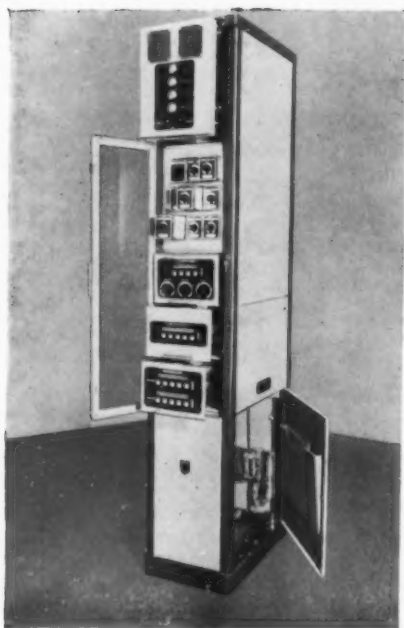
Tempomat Control Units

PHILIPS Industrial Division announce the introduction of a new range of electronic control equipment for resistance welding applications. This equipment, known as the Tempomat Series P.E.5000, is available in four cabinet sizes, depending on the complexity of the welding programme cycle to be controlled. Combinations of a range of units, within six standard panels, permit the building up of at least 180 different arrangements of welding sequence to cover every possible welding requirement.

The most simple arrangement of units, comprising an ignitron contactor unit and synchronous thyatron firing unit, is contained in the P.E.5010 cabinet. If required, a simple non-synchronous timer and heat control can also be incorporated, if these are not already available in the welding machine. The intermediate sizes of cabinet P.E.5014 and P.E. 5018 allow additional units to be incorporated with a corresponding increase in complexity of programme control of the welding cycle.

The largest unit P.E.5020 is designed to accommodate the widest range of functions which would be required for any welding sequence, such facilities as pre-heat and post-heat control, pulsation welding with slope control, and a range of timing units to control pressure cycles, etc., being provided.

Common to all the equipments is the ignitron contactor unit, which is designed to accommodate any of the three sizes of Philips ignitrons, types P.L.5551, P.L.5552



and P.L.5555, giving a wide range of welding power from 600 kVA at 5.3% duty cycle to 2,400 kVA at 30% duty cycle. A waterflow switch is provided to interlock the equipment against failure of the water supply cooling the ignitrons.

With the exception of the ignitron unit, which is accessible via a door at the base, all the remaining units are readily removable, and slide into the cabinet on rails. Flexible leads enable the units to be operated in the withdrawn position, for inspection and adjustment. The controls are clearly marked, and the value of the welding current and other functions can be readily re-set, as the occasion arises.

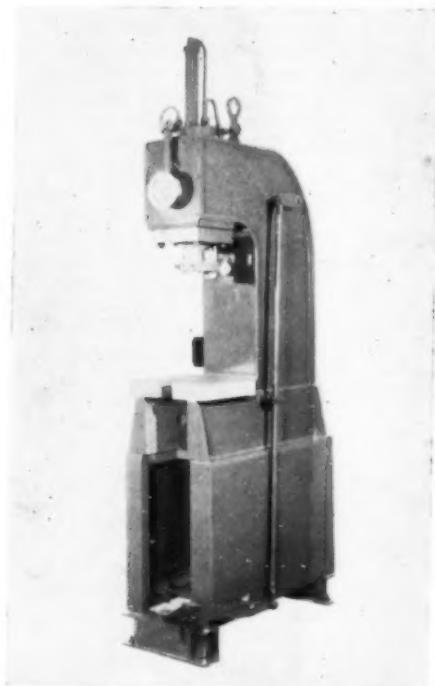
The Tempomat can be used with all types of spot, seam and projection welding machines: it will considerably increase the range of functions that can be carried out by existing machines and will provide them with accurate electronic control. This is particularly important where new or difficult materials have to be welded, or where complex welding cycles are required. Old or simple types of equipment can thus be brought completely up to date with a corresponding improvement of output and quality. Operator fatigue, so frequently a cause of inconsistent quality, is entirely eliminated because, once set, the equipment operates fully automatically throughout each successive welding cycle. Once the setting has been adjusted by a skilled welding engineer, a complex welding process can be carried out with normal operators. The compact and centralized control panel of the Tempomat can easily be re-set for a completely different cycle of operations within a few minutes.

Although the Tempomat finds particular application in the production shop, the fact that the separate functions are so readily controlled, both in time and amplitude, makes it an extremely useful equipment for welding development work, where it enables the research and development engineer to establish precisely

the correct welding cycle required for any given job. *Philips Electrical, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.*

15 Ton Hydraulic Press

On a new 15-ton hydraulic press, the ram pressure is adjustable, by turning a small handwheel, between 1 and 15 tons. The ram is of 2½ in. O.D., with a tool socket 1 in. × 2½ in. deep. Reliable oil sealing is provided by four piston rings, and a 2 in. O.D. guide bar is firmly linked to the main ram. The pump, of Pilot design, is of the twin cylinder, plunger type, with an oil tank of 6 gal. capacity. The high-pressure fluid circuit is fully protected by a special overload valve. Increased operating speed is obtained by the ram having a power return stroke.



This Model 4 press has a daylight of 16 in., with a throat of 8½ in. and an 8 in. stroke. The motor is 4 h.p. operating on 400/440 volts, three-phase, 50 cycles supply, and having a speed of 950 r.p.m. For a full 8 in. stroke, the operating speed is 2½ seconds down and 1½ seconds up. Operation of the press is simply effected by means of two foot controls, one for down movement and the other for power return: this is variable and the speed is controlled by the pressure applied by the operator.

This Pilot press is extremely compact, occupying a floor space of 17 in. × 34 in., and having an overall height of 7 ft. 2½ in.: the weight is under 10½ cwt. Great attention has been paid to ease of maintenance, all parts being readily accessible, and the bedplate, measuring 12 in. × 14 in. with a central slot of 2½ in. × 7 in., is retained in position by four ½ in. Allen screws and is easily detached.

Pilot Works, Ltd., Manchester Road, Bolton, Lancs.



"I shall have to see a specialist" *decided the Dragon*

"My fire-breathing apparatus isn't all it ought to be these days. I think I'll contact Shell-Mex and B.P. Ltd. and take advantage of their technical service. They've helped to develop some of the most

successful heating processes in modern industry, so they ought to be able to cope with mine. It's no good sticking to obsolescent methods when the most go-ahead concerns are changing to oil-firing."

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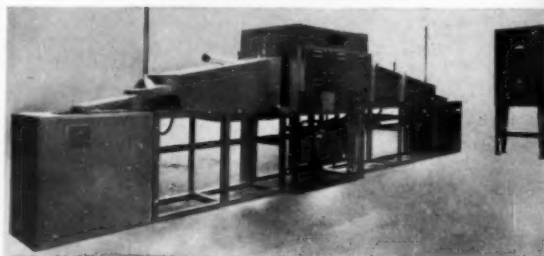


Illustration shows 21 kW. 7½" wide conveyor furnace incorporating the principle of the Hump Back. Special features are transformer controlled heating element: variable speed conveyor: controlled atmosphere throughout working chamber: fully automatic control equipment. Temperatures up to 1150° cent.

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Nash and Thompson Metallurgical Mounting Press

A machine for the quick mounting of specimens for metallographic work, based on the press designed by the British Non-Ferrous Metals Research Association.

The press is available with cylinders diameter 1 in. $1\frac{1}{4}$ in. and $1\frac{3}{4}$ in. These are mounted with the ram in a single unit so that the mould can be formed and ejected with an axial force.

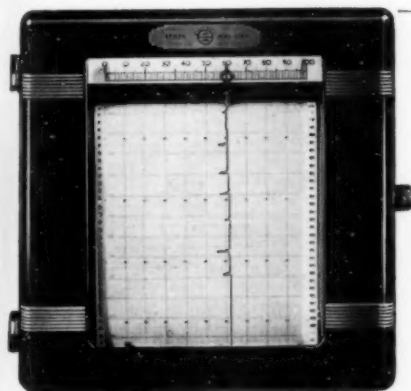
The heating element is rated at 600 watts to give a reasonably quick rate of working, and a water cooling coil is built in to the cylinder wall. Moulds up to 2" deep can be produced in approximately ten minutes. $10" \times 12" \times 18"$ high. Weight 76 lbs.

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It can be calibrated to measure D.C. down to 10 M/V with an accuracy of 0.1%. Also suitable for A.C. or D.C. Balanced Bridge circuits.

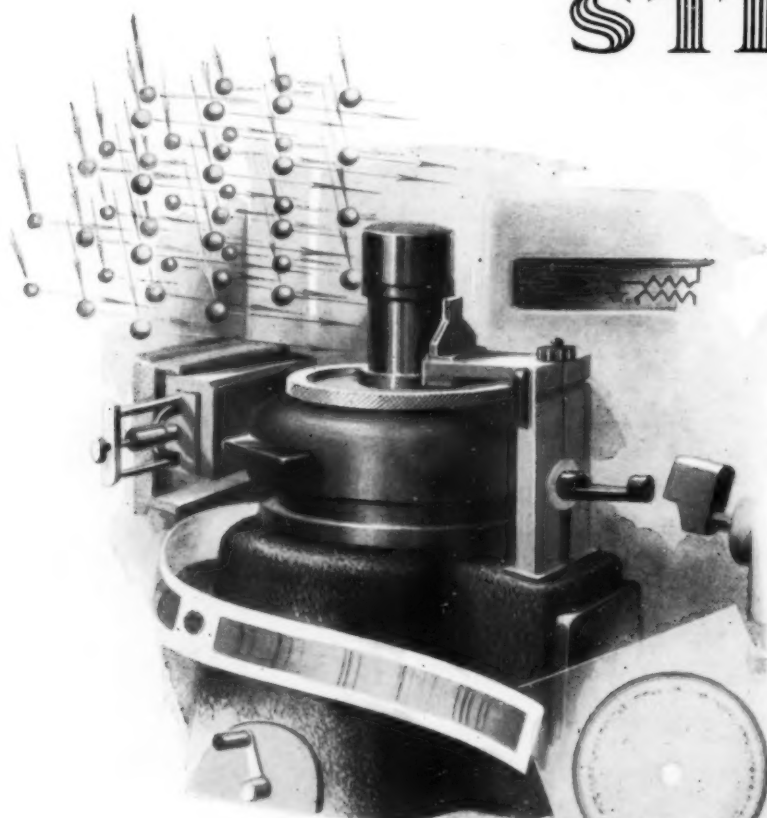
The graduated width of chart of 10" enables the high accuracy and rapid response of the "Wide-strip" to be used to the greatest advantage.

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In crystalline materials, which include steel, the constituent atoms are arranged in an ordered pattern or space lattice on planes at definite intervals. X-ray crystallography enables these internal structures to be determined directly.

In one method, a thin beam of X-rays is directed on to a specimen of the steel or other material held at the centre of a special camera carrying a band of photographic film. The crystallographic planes of atoms in the specimen diffract part of the beam at definite angles producing lines on the film that correspond to the lattice spacing.

In metallurgical research, X-ray diffraction is used for identifying phases in complex alloy systems. For routine work it provides rapid and positive information as to the nature of steel constituents and associated materials such as carbides, inclusions, slags and refractories.

The instrument depicted here is designed for operation at elevated temperatures so that transformations in the steel can be followed.

This is the fifth in a series of illustrations of highly specialised equipment devised to control the production and testing of special steels by

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LABORATORY METHODS

MECHANICAL • CHEMICAL • PHYSICAL • METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

OCTOBER, 1954

Vol. L, No. 300

Analytical Standardisation in the Iron and Steel Industry

By J. O. Lay, F.R.I.C.

Metallurgy (General) Division, British Iron and Steel Research Association

Starting as a tentative commitment of the Iron and Steel Institute in 1918, co-operative investigation of methods of analysis has assumed a steadily increasing role in the research programme of the iron and steel industry. At the present time the Methods of Analysis Committee of the British Iron and Steel Research Association is responsible for a continuous flow of analytical work which plays a valuable part in solving manufacturing problems and facilitating the development of new materials. It is emphasised that in many instances the results of accurate chemical analysis are of fundamental importance in other research or investigatory work.

Introduction

THE successful production, processing and fabrication of iron, steel and related materials depends to a very large extent upon precise knowledge and careful analytical control of composition through all the stages of manufacture. Information is required, not only about the metal itself, but also about the raw materials and by-products which form an essential part of the iron- and steel-making operations. The development of analytical methods in this field of chemistry is, therefore, necessary.

Most industrial laboratories use analytical techniques which have been devised to meet particular circumstances, and until fairly recently those in the iron and steel industry were no exception. Unfortunately, while suitable procedures can easily be devised for internal use, the growing interchange of research results and works practice between various establishments has shown more and more clearly that these procedures are not necessarily reliable for determinations on samples differing from those originally examined, neither will they always be sufficiently accurate to meet the requirements of more rigid specifications.

As long ago as 1918 this trend was recognised by the Iron and Steel Institute, which set up, among others, a co-operative research committee dealing with metallography, chemistry and physics. This committee carried out much useful work, but it was not until 1939 that a special sub-committee under the chairmanship of Dr. E. Gregory was appointed by the Heterogeneity of Steel Ingots Committee, a joint committee of the Iron and Steel Institute and the British Iron and Steel Federation, to develop and improve analytical methods. The renewed impact of war conditions undoubtedly contributed to the decision to co-ordinate work along these lines, and one of the first projects before the sub-committee was concerned with the determination of

sulphur and phosphorus in mild steel, results for which by various analysts could be found to disagree by as much as 0.005% at a time when specification limits could lead to rejection if the figures obtained by producer and consumer differed by 0.002%.

The use of lead for free-machining came into prominence about the same time, and the first report of completed work by the sub-committee¹ gave rise to Part 1 of British Standard 1121, "Standard Methods of Analysis for Iron, Steel and Ferro-Alloys: The Determination of Sulphur, Phosphorus and Lead." The sub-committee continued work on other methods until its responsibilities were taken over by the Methods of Analysis Committee, one of the committees set up in the Metallurgy (General) Division when the British Iron and Steel Research Association was formed during 1946. The chairmanship of this committee is still held by Dr. Gregory, now Research Director of Messrs. Edgar Allen & Co. Ltd., Sheffield, who has, therefore, been associated for over 15 years with the development of methods of analysis for iron and steel.

A historical introduction dealing with this subject would not be complete without reference to the Blast Furnace Raw Materials Sub-Committee of the Iron and Steel Industrial Research Council, also formed during the 1939-45 war, which published some recommended analytical methods in 1944, and whose work is now being continued by a sub-committee of the Methods of Analysis Committee; to the formation of other analysis committees in limited fields, such as by the Permanent Magnet Association in 1945 and by the British Cast Iron Research Association in 1950; to the setting up of discussion groups in various parts of the country; and to the great part which has been played by internal committees in organisations such as the United Steel Companies, Ltd., Richard Thomas & Baldwins, Ltd., and Imperial Chemical Industries, Ltd. Many of the

TABLE I.—TYPICAL RESULTS FROM LABORATORIES USING VARYING ANALYTICAL METHODS (1939-1943).

Laboratory	Sample M4317 % Sulphur	Sample M4401 % Phosphorus	Sample M4211 % Tin	Sample M4876 % Tungsten
A	0.062	0.090	0.130	0.60
B	0.069	0.088	0.144	0.69
C	0.072	0.090	0.081	0.75
D	0.073	0.086	0.110	0.73
E	0.065	0.084	0.133	0.68
F	0.070	0.089	0.102	0.60

learned societies also have standing committees dealing with analytical techniques, many of which find application in the ferrous industry.

The effect of standardising analytical methods can be appreciated by a comparison of the results in Table II with those in Table I.

Committee Organisation

As the Research Association may well be considered the central co-ordinating body for research into metallurgical problems, it may be asked why the investigation of analytical procedures is not carried out almost entirely in the Association's own laboratories. These laboratories were set up in Sheffield in order to provide analytical services to the various divisions of the Association, and to carry out research on general analytical techniques². It was never envisaged that they might replace the committee structure, which has proved most satisfactory for its purpose, although a certain amount of attention is in fact devoted to work arising from current committee projects. The present committee approach originates from the history of development of analytical research in the industry, and has been found most appropriate in its method of bringing together analysts with practical knowledge of the difficulties which can be encountered, and with laboratory facilities for investigation of such difficulties. It also ensures that every proposal is examined and accepted by a representative group of such analysts. Each analytical method is, therefore, tested in a wide variety of conditions which no individual laboratory could hope to reproduce, and authoritative statements on its reliability and scope can be justified.

The Methods of Analysis Committee consists of twelve members drawn from the iron and steel industry, user firms, academic, government and other research establishments, and co-ordinates the activities of five similarly constituted sub-committees (Fig. 1), which together cover the whole field of interest. The latter not only includes analytical procedures for iron and steel, raw materials and by-products, but also embraces sampling and some aspects of non-destructive testing. The role of the Research Association is to assist in the co-ordination of activity; to correlate and circulate information; to ensure publicity for research results; and generally to

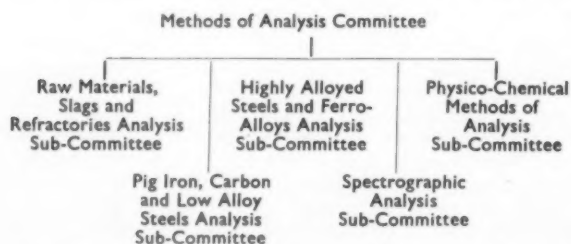


Fig. 1—Structure of the B.I.S.R.A. Analytical Research Committees.

TABLE II.—TYPICAL RESULTS FROM LABORATORIES USING STANDARD METHODS. (1949-1953).

Laboratory	Sample MGS/174 % Sulphur	Sample MGS/164 % Phosphorus	Sample MGS/198 % Tin	Sample MGS/79 % Tungsten
G	0.043	0.079	0.172	0.56
H	0.045	0.080	0.174	0.53
I	0.044	0.081	0.171	0.54
J	0.043	0.081	0.176	0.55
K	0.045	0.082	0.170	0.53
L	0.044	0.079	0.169	0.56

provide secretarial services to the committee in order to facilitate its work, while, as has been stated, the Metallurgy Division's Analytical Laboratory is often able to make a practical contribution to the progress of particular investigations.

The method of approach to any particular analytical problem is as follows:—

- The field of investigation is precisely determined.
- The combined experience of members is assembled, correlated and amplified by literature references.
- An analytical procedure is formulated, based either on existing practice or on theoretical considerations.
- The procedure is applied to a group of samples circulated to all the co-operating analysts, results being sent in independently.
- Modifications are introduced, if required, and examination continued until a satisfactory procedure has been developed.
- A report of the investigation is prepared, containing all relevant information and analytical results.
- The conclusions reached during the research are publicised. (see Section on Publicity).

Sampling techniques form an important aspect of analytical standardisation, since gross variations are commonly encountered in bulk supplies of some of the materials examined, particularly natural minerals (Table III).

As a part of its work, therefore, the Committee has been responsible for recommending sampling procedures which have been embodied in British Standard 1837: 1952, "British Standard Methods for the Sampling of Ferrous Metals and Metallurgical Materials for Analysis—Part 1, Iron and Steel, Part 2, Ferro-Alloys." However, it must be pointed out that all the samples circulated for co-operative analysis are carefully prepared to ensure homogeneity, so that the possibility of introduction of error from this source is avoided.

Analytical Problems

The present state of knowledge in the field of analytical chemistry might easily lead to the conclusion that no serious problems exist for the iron and steel works chemist. As far as routine control analysis is concerned, this conclusion is to a large extent correct, but the accuracy required for internal control may often be utterly inadequate when sales promotion is in question. It cannot be too strongly emphasised that, whereas the watchword in control analysis is *speed*, to which a measure of accuracy may be sacrificed, only procedures of the highest reliability can be employed when specification requirements and sales competition have to be met. Occasionally, as in the development of direct-reading spectrography, it may appear possible to have the best of both worlds, but this can usually only be

TABLE III.—VARIATIONS IN COMPOSITION OF SAMPLES FROM BULK MATERIAL.

Material	Sampling Method	Range of Composition	Average Analysis
Steel Ingot ..	Milled cross section at intervals along ingot.	Sulphur 0.085-0.12%	0.10%
Ferro-Chromium ..	60 mesh sample separated on 200 mesh B.S. sieve.	Chromium 63.9-66.45%	65.7%
Iron Ore	Separate samples from the same ore-bed.	Iron 24.6-33.6%	—

achieved at prohibitive cost. The Methods of Analysis Committee has a primary responsibility to develop standard methods which will enable the results of analysis to be reproducible from laboratory to laboratory, and must take into account the needs of the analyst who has to rely exclusively upon "wet analysis," as well as those of his better-equipped colleague. For this reason, modifications of classical volumetric and gravimetric techniques assume equal importance with the more modern physico-chemical and spectrographic procedures. It has also been an aim of the committee to devise, wherever possible, methods which have such a wide scope that they can be applied to a whole class of materials rather than to a limited number of particular types; for this reason, some of the procedures recommended have been less simple than would otherwise have been the case, but the discerning analyst is usually able to identify any operation which can be omitted without prejudice to his own determination on a sample of approximately known composition.

Some of the earliest researches have already been mentioned, and the results of subsequent investigations have been published at frequent intervals, but it is significant that the volume of work before the Committee does not appear to decrease. During the past few years attention has been directed to sulphur-partition between slag and metal in blast-furnace operation, and one series of projects undertaken by the Committee was the preparation of reliable gravimetric and combustion methods for the determination of sulphur in blast-furnace slag, iron and steel^{3,4}. A major research recently completed provided an assessment of the familiar stannous chloride reduction procedure for the determination of iron, and recommended the use of hydrogen sulphide as a reducing agent in a more comprehensive and reliable method⁵. Among procedures specially applicable to finished products, the determination of nickel has aroused particular interest, owing to the need for precautions to overcome interference from copper and cobalt (Table IV).⁶

Spectrographic analysis has been under continuous review, and a recommended scheme for the analysis of low-alloy steel has been drawn up,⁷ based on a series of standards prepared for this purpose, while further research is in progress on the determination of residuals in mild steel, the analysis of slags and other non-metallic samples, and the use of solution techniques. Physico-chemical methods of analysis have also been examined, the determination, respectively, of molybdenum, tungsten and vanadium having required detailed consideration, because of the interaction of these elements in any absorptiometric procedure^{8, 9, 10}. In view of the importance of boron as a "trace" alloying element in modern steelmaking, it has also been necessary to investigate rapid and accurate methods for the determination of this element, while in other instances

TABLE IV.—INFLUENCE OF COPPER AND COBALT ON NICKEL PRECIPITATION. [STEEL K3778 (0.1% NICKEL) WITH 2% NICKEL ADDED].

Analyst	Results by First Draft Method			Results by Recommended Method		
	No Addition	With 2.5% Copper	With 12.5% Cobalt	No Addition	With 2.5% Copper	With 12.5% Cobalt
M	2.10% Ni	2.21% Ni	0.5% Ni	2.09% Ni	2.10% Ni	2.10% Ni
N	2.10% Ni	2.31% Ni	0.2% Ni	2.10% Ni	2.11% Ni	2.12% Ni
O	2.08% Ni	2.34% Ni	not determined	2.08% Ni	2.08% Ni	2.07% Ni
P	2.11% Ni	2.18% Ni		2.09% Ni	2.08% Ni	2.09% Ni

colorimetric methods have been perfected as alternatives to more tedious gravimetric or volumetric procedures.

While the contribution of these investigations to the increasing precision of steel analysis can be readily recognised, it must be emphasised that they are also of value in relation to general metallurgical research. Slight variations in composition profoundly affect the properties of many present-day steels, and absolute accuracy in the determination of trace elements is essential in order to extend fundamental knowledge of steelmaking processes. One major research now being undertaken by the Committee is the precise chemical analysis of a new series of spectrographic standards containing trace amounts of many common residual elements, while the determination of gases in steel is also receiving attention.

Publicity

The work of the Methods of Analysis Committee would be of only limited value if its results were not given the widest possible publicity. A full report is prepared at the conclusion of each investigation and these reports are submitted for publication in appropriate technical journals. Furthermore, the recommended analytical methods are presented to the British Standards Institution for consideration, and, after having been circulated to industry in general for comment, are usually adopted as British Standards. In order to keep pace with the growth of scientific knowledge, these Standards are reviewed at frequent intervals, and modifications introduced wherever these can be shown to improve the reliability of the methods. There are at present 31 parts of B.S. 1121 "Standard Methods for the Analysis of Iron, Steel and Ferro-Alloys," many of which include alternative procedures, covering a significant portion of the field of ferrous analysis.

Progress reports are often made available to members of the iron and steel industry while the work is in hand, and each year analysts from steelworks laboratories are invited to a conference at which completed, current and future investigations are discussed. Representatives from allied industries and other establishments also attend these conferences, which provide an opportunity for the free exchange of information, the consideration of fresh problems, and the presentation of papers dealing

TABLE V.—ATTENDANCE AT B.I.S.R.A. CHEMISTS' CONFERENCES

Year	Iron and Steel Industry	Users	Academic and Government Laboratories	Research Associations	Miscellaneous	Total
1947	65	17	10	11	4	107
1948	67	16	8	12	4	107
1949	63	24	5	13	3	107
1950	69	29	4	18	3	123
1951	63	36	5	20	7	131
1952	58	32	7	12	6	115
1953	66	50	12	18	17	163

with new analytical techniques. The record of attendance at these conferences affords the best indication of the importance attached by interested organisations to the work carried out by the Committee (Table V).

A very useful complementary service is provided by the Bureau of Analysed Samples, Ltd., which has assumed responsibility for the preparation, analysis and sale of material of guaranteed composition for use in analytical standardisation. Many of the samples of ferrous material have been analysed by representatives of the iron and steel industry, using methods recommended by the Committee and adopted as British Standards, and these samples can be employed with confidence for reference purposes in the course of routine or precise chemical and spectrographic analysis. A limited range of accurately analysed samples can also be obtained from other suppliers.

Conclusion

For well over thirty years, the iron and steel industry has been signifying its appreciation of the vital importance of accurate analytical technique by its support for the idea of co-operative research in this field. During this period the organisation of such research has grown from the original limited attempts by individual laboratories, and the early collaboration of a few enthusiasts, to a smoothly-functioning unit to which the whole industry can contribute. In this period also, recognition has been accorded to the responsible role of the chemist in industry, to the need for precise techniques which provide reproducible results between laboratories, and to the possibilities afforded by accurate control of composition for the development of new and improved products. While speed may be essential in the control laboratory, precision is generally of paramount importance in the final analytical examination of any sample, and, while standardised operational techniques can ensure the latter objective, the growing use of ancillary equipment may enable the analyst to reduce the time required for accurate analysis and thereby bring these objectives closer together.

Until classical methods of analysis are entirely superseded, a situation unlikely to arise in the foreseeable future, the Committee's main responsibility must be to seek perfection amongst such methods, but it must also examine and report on each progressive step in the production of new equipment which may facilitate the analyst's task. With this aim, the Methods of Analysis Committee is keeping the changing situation under continuous review, and is noting modern developments in the fields of spectrography, absorptiometry, X-ray fluorescence analysis and allied techniques. To achieve the most valuable and far-reaching results in analytical standardisation, and to ensure that every prospective advantage is thoroughly exploited, will continue to require a considerable contribution from the resources of the Research Association and of interested industrial organisations.

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 - 3 *J. Iron Steel Inst.*, 1953, **174**, May, 28-30.
 - 4 *Ibid.*, 1954, **177**, June, 235-242.
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 - 6 B.I.S.R.A. Paper MG/D/175/53—not yet published.
 - 7 Iron & Steel Institute Special Report No. 47, 1952.
 - 8 *J. Iron Steel Inst.*, 1952, **172**, Dec., 413-415.
 - 9 B.I.S.R.A. Paper MG/D/16/54—not yet published.
 - 10 B.I.S.R.A. Paper MG/D/271/53—not yet published.
- Information about other published work of the Committee can be supplied on request.

Correspondence

Presenting a Technical Paper

The Editor, METALLURGIA.

Dear Sir,

How right is the advice contained in the text of Mr. J. F. Kayser's letter in the May issue; and to my mind Mr. R. J. Brown's letter in the July issue fully confirms this. Mr. Brown says the speaker who can talk for an hour on brief notes is unusual. Of course he is right. So many technical discourses have been read because the authors have never tried to deliver their addresses.

May I suggest that the interest of the profession will be much furthered by the advent of a much larger number of technicians who are able "to deliver the goods" as a speech with at least some of the simpler devices of oratory rather than the monotonous reading of a written text.

There must be a beginning; and the right time to begin is when you are young. Certainly the young speaker can be sure of a sympathetic hearing from a technical audience; so that he need not be disturbed on that account.

To my mind, it was rather naughty of Mr. Brown, and rather irrelevant, to drag in Sir Winston Churchill's speeches. No responsible politician ever delivers a speech without adhering closely to a prepared text. The fate of nations may well be influenced by what he says; worse still, an indiscreet comment may plunge him into a verminous pit!

Yours faithfully,

G. W. WEEKS,

Chief Metallurgist, De Havilland Aircraft Division, Hatfield. 28th September, 1954.

A New Name Cast in an Old Tradition

Two well-known and old-established Stoke-on-Trent non-ferrous foundries, T. M. Birkett and Sons Ltd., and Billington and Newton Ltd., have amalgamated. The company will be known as T. M. Birkett, Billington and Newton Ltd., and will be one of the largest non-ferrous founding firms in the country. The Board of Directors will be: A. P. Wright (Managing Director), J. C. M. Shekell, A. Birkett, E. Y. Birkett and F. Bennet, and the headquarters of the company will be a newly-erected administrative block at Hanley which includes spacious office accommodation, drawing offices and a laboratory. The foundries and machine shops at both Hanley and Longport will, of course, remain in operation and each will continue to offer a personal service to its own customers as in the past.

Birkett, Billington and Newton make castings ranging in size from a few ounces to 10 tons in a variety of non-ferrous metals, including phosphor bronze, gun-metal, aluminium bronze, manganese bronze and light alloys. Many unusual and exacting castings have been entrusted to the firm by the Admiralty and some of the best known names in British industry. One particularly interesting job completed recently was a turbine runner casting in aluminium bronze for a 3,600 h.p. Turgo impulse wheel. The specification called for a tensile strength of 45 tons/sq. in and a high resistance to erosion, corrosion and abrasion. Other specialities are centrifugal-cast wheel blanks and chill-cast phosphor bronze rods and tubes for bushes and bearings.

Some Experiences with a New Metallurgical Mounting Plastic

By P. A. Lovett

Following a brief outline of a method of mounting microspecimens in a new cold-setting plastic, prior to grinding and polishing, the author discusses a number of points which have arisen during twelve months use of the process.

JUST over a year ago, the author reported* on development experiments with a new cold-setting plastic which is now known as N.H.P. Mounting Plastic.† Since then a number of laboratories have tried out the methods outlined in the article, and the makers report a continued interest in this material.

Equipment Required

The plastic materials used consist of a fine white powder and a colourless volatile liquid. When combined in the proportions of approximately 2 : 1, respectively, the constituents polymerise into an almost colourless acrylic resin in from 2 to 30 minutes, depending on the conditions of mounting.

The moulds are of the simplest character, as may be seen from Fig. 1. For cold mounting, 1 in. lengths of $1\frac{1}{4}$ in. O.D. \times 10 S.W.G. brass tube are parted off on a lathe: in use they are mounted on a glass plate or flat metal sheet. In the case of hot mounting operations, 3 in. lengths of the same tube are fitted with two $\frac{3}{4}$ in. long plugs, which should be an easy sliding fit in the tube. It is an advantage to chromium plate and polish the plugs and the inside of the mould. Pressure is applied by means of a 3-in. G clamp (Fig. 1).

Mounting Techniques

Cold Mounting without Applied Pressure.

The specimen is placed face downwards on the previously greased plate glass, and a brass ring placed over it. Two parts of powder are now poured in, and

then completely saturated with approximately one part of liquid. 7 ml. of powder and 3-4 ml. of liquid gives a mount 1 in. diameter by $\frac{5}{8}$ in. thick.

If it is possible to stir the mixture lightly without disturbing the sample, then this should be done as it sometimes prevents bubbles adhering to the sides of the sample. A further technique which has so far overcome this difficulty is to pour only a little powder into the mould followed by the appropriate proportion of liquid to give a layer about $\frac{1}{8}$ in. thick. This is left to stand for 3-4 minutes before the balance of the powder and liquid is added.

Any excess liquid usually drains away at the mould/glass interface, but to speed the setting process it is wise to remove any supernatant liquid with a medicine dropper after about two minutes. After 20-30 minutes the mould can be removed from the glass plate, and the mount tapped through with a rod and hammer. In a very cold room (say 45° F.) the setting time may be as long as an hour. If the supernatant liquid is not removed the bulk of the plastic sets hard in about 20 minutes, but a sticky layer about $\frac{1}{8}$ in. thick is left at the top which takes 6-10 hours to harden.

Cold Mounting with Pressure.

The 3 in. length of tube and the plugs are used along with the G clamp for this method of mounting. The sample is placed face downwards on the lower plug and the tube fitted over the plug. Powder and liquid are added as before and the top plug pushed in. The mould is then carefully placed in the G clamp and pressure applied to maximum hand tightness. After 4 minutes there is a certain amount of contraction to take up and the clamp is again tightened. After a further 6-8 minutes the mount can be removed by tapping the two plugs, with the mount between them, through the tube.

Hot Mounting with Pressure.

The procedure is the same as for the preceding method until the G clamp is first tightened. The clamp is now transferred to a pan of boiling water and placed vertically so that the water is roughly half way up the mould. Tightening must now take place every five seconds for a total of about 30 seconds, after which time the total contraction should have been taken up. The clamp is now left for a further $1\frac{1}{2}$ minutes (longer times make no difference) and then cooled under a tap (for convenience only). The mount is tapped through as before.

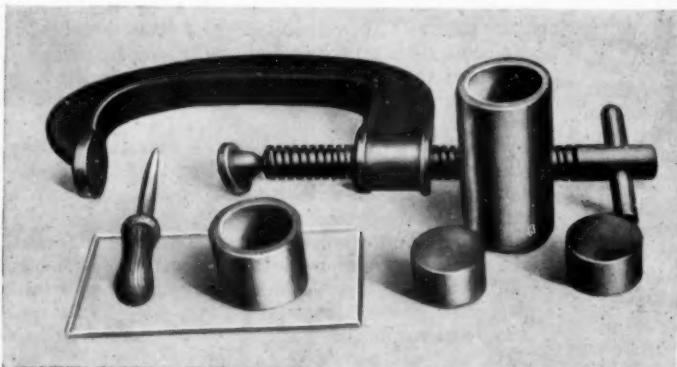


Fig. 1.—Equipment for hot pressure mounting (right) and cold pressureless mounting (left).

* *Metal Industry*, 1953, July 24th.

† Manufactured by North Hill Plastics Co., Ltd., Manley Court, Stoke Newington High Street, London, N.16.



Fig. 2.—Cold-mounted in an open mould.

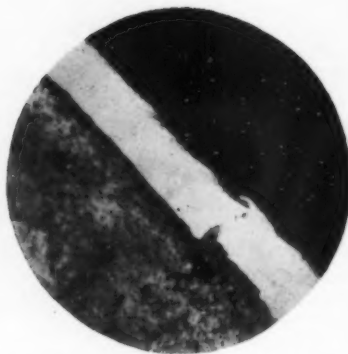


Fig. 3.—Cold-mounted in an open mould with hardener addition.

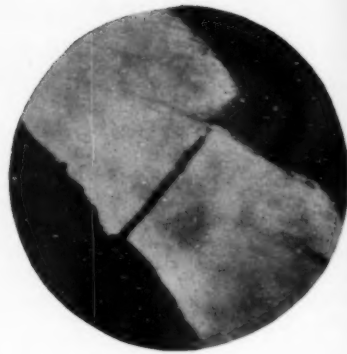


Fig. 4.—Hot-mounted at 100° C.

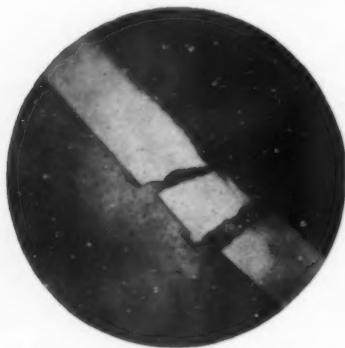


Fig. 5.—Hot-mounted at 100° C. with hardener addition.



Fig. 6.—Cold-mounted with pressure.

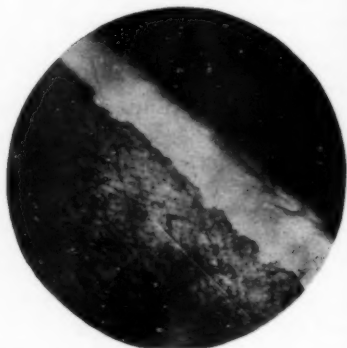


Fig. 7.—Perspex-type mount.

Figs. 2-7.—Photomicrographs of chromium-plated steel illustrating the effects of different methods of mounting on the quality of the edge preparation. $\times 1000$

Discussion

The hot mounting method gives a clear mount, whilst the cold mount made with the aid of pressure is translucent. The cold mount made in an open mould is semi-transparent, having a large number of minute air bubbles distributed throughout its body.

One of the difficulties encountered in using mounting plastics is to find one with sufficient abrasion resistance to support the edge of the sample during polishing without wearing away—a process which causes the edge to become rounded. The hot mounts (Figs. 4 and 5) have the greatest abrasion resistance and give good edge preparation, but the cold mounts (Figs. 2 and 3) are excellent and somewhat better than the ordinary Perspex type mount (Fig. 7). A special hardener liquid* is available for use with really difficult specimens which have extremely hard edges. This liquid is added to the first liquid and the results for chromium-plated steel samples mounted cold (without pressure) and hot, both with the hardener addition, are shown in Figs. 3 and 5. A similar sample mounted cold (under pressure) without the hardener is shown in Fig. 6. The method of preparation was the same in all cases, coarse filing; dry emery papers down to 0000 grade; wet polishing on a fast, Selvyt-covered wheel with coarse Microid alumina; and, finally, by a brief hand polish on a pad of Microid fine alumina. The mounts were washed and dried between each emery paper, and the wet polishing time was kept

approximately constant for each sample. The magnification in *all* cases was 1,000, and the point of focus was the chromium-steel interface, in order to compare any rounding of the edge from one method to the next. It is appreciated that better methods are available for the edge preparation of difficult samples, but these would not demonstrate the remarkable ability of this new plastic to give good results under ordinary polishing conditions.

Notes

N.H.P. Mounting Plastic is not affected by any normal etching reagents and is reported not to crack in boiling sodium picrate. It is dissolved by acetone but benzene and alcohol have no adverse effect.

Provided the hardener is not added, the mounts are tough enough to allow identification numbers to be stamped on the reverse side.

Opaque black mounts can be made by using the liquid in the coloured form which is also available: other colours can be obtained by arrangement. It must be admitted that, although the plastic is highly effective in use, the mounts are not as attractive to look at as those made in other plastics, and the use of the black liquid certainly gives the mount a smart workmanlike appearance.

The hardener liquid gives the plastic great adhesive powers, and it is advisable to lubricate the mould with castor oil or liquid paraffin. Further, the hardener (only) reacts vigorously with magnesium alloys, and these can

* N.H.P. 123.

only be successfully mounted by the hot method... once set the plastic ceases to react. However, as the abrasion resistance of the normal plastic is ample for magnesium, there is no point in making the hardener addition in these cases.

Metal powders can be mounted by mixing them with the plastic powder and using the black coloured liquid, for preference, to cut down internal reflection.

If the inside surface of the cold mounting mould becomes scored or dented in use, the mount may be difficult to extract. A simple remedy is to line the mould with a layer of cellophane paper, using a new lining for each mount.

There is no violent exothermic reaction when the plastic polymerises, and the temperature does not normally rise during mounting, but certain exceptions have sometimes been observed when using steel tubes for mould material, or when mounting steel specimens. On these occasions an exothermic reaction is catalysed, the

temperature rises quickly and the plastic sets hard in four or five minutes in the open-type mould. The temperature does not exceed 50°C. One thing is certain, the author has not been able to make the reaction work twice running with the same specimen, moulds, etc.

Conclusions

In the author's experience, now backed up by that of a number of laboratories, the plastic has proved useful and efficient and a great time saver. It is a distinct advantage to be able to set up two or three samples in open moulds in less than five minutes knowing that one can then leave the process to look after itself. Furthermore, there is no mess or waste of materials.

Acknowledgments

Acknowledgments are made to the management of Messrs. H. Rollet & Co., Ltd., for permission to publish the results of the experiments performed in their laboratory.

Exhibits of Metallurgical Interest at the Physical Society Exhibition

The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.

Emission from Worked Surfaces

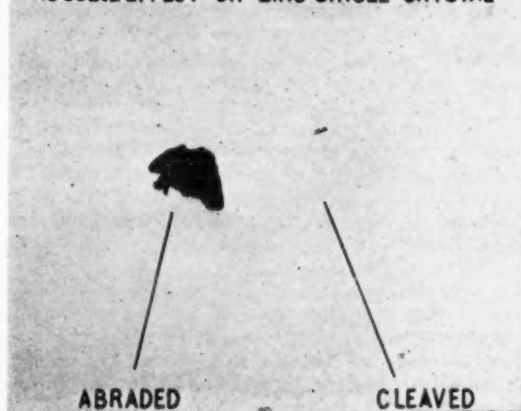
FRESHLY abraded surfaces and evaporated films of some metals (e.g., aluminium, cadmium and zinc) show a photo-electric effect in the visible range of light, and cause the formation of images on photographic plates. These effects are not observed with aged or undisturbed surfaces. They are believed to be due to the presence of definite structures, such as oxygen-ion vacancies (F-centres), in the lattice of the oxide covering the surface.

If light of a definite wavelength is allowed to fall on an abraded or evaporated surface containing F-centres, electrons are emitted. In the presence of oxygen, negative ions (O_2^-) are formed which are directed by an electric

field into a windowless Geiger-counter and registered on an oscillograph and scaler. The emission/wavelength curve shows a sharp maximum at 4,700Å, indicating that the F-band lies about 2.6 electron-volts below the conduction band of the oxide. Only a few of the electrons raised into the conduction band are emitted (quantum efficiency $\sim 10^{-9}$).

Oxide surfaces containing F-centres are very reactive chemically, and form hydrogen peroxide from oxygen and water. This reaction can be used to record the phenomenon photographically, since the traces of hydrogen peroxide produce an image on photographic plates. This is illustrated here by cleaving a single crystal of zinc. One of the cleavage faces has been abraded and the other left undisturbed. As will be seen, only the abraded surface produces a photographic image.

RUSSELL EFFECT ON ZINC SINGLE CRYSTAL



Vapour Booster Pumps

The new vapour booster pumps made by W. Edwards & Co. (London), Ltd., have been on field trial in various applications for some time and have proved their great value to industrial vacuum pump users. Unique in Europe, their highest pumping speed is available in the vital industrial high vacuum region of 10^{-1} to 10^{-2} mm. of mercury. This vacuum performance enables gas flow to be handled by a smaller backing pump and line, while baffle valves, demountable vacuum joints, and other features of the well-known Speedivac vapour pump range are retained. The pumps give economical operation compared with alternative methods, and will be found invaluable for such applications as de-gassing units, vacuum stills, vacuum furnaces, etc. Their importance will be appreciated when it is considered that they have their highest speeds at just that pressure

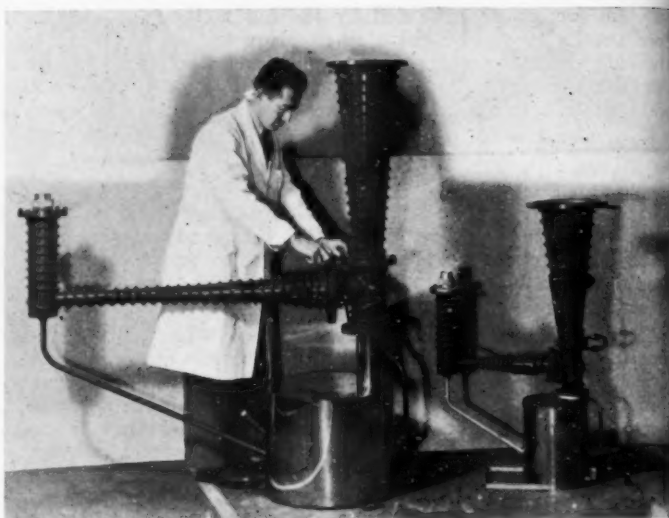
where the performance of the rotary backing pump is losing its effectiveness, yet a vapour diffusion pump has not by any means gained the highest pumping speed possible for the type. The ultimate vacuum attainable is better than 10^{-4} mm. of mercury, and the Model 9B1 has a peak speed (unbaffled) of 45-50 litres/sec. at 2.25 kW., whilst the corresponding figure for the Model 9B3 is 900 litres/sec. at 2.25 kW., the recommended backing pump displacement being 450 litres/min. in each case.

Ultrasonic Flaw Detection

The Ultrasonoscope is a portable flaw detector, made by Glass Developments, Ltd., which can be used with either single or double probe techniques, and hence is suitable for a very wide range of problems. A number of new probes for use with this instrument have been developed including a new type of transverse wave probe developed for single probe (common transmit-receive) work. Barium titanate is used as the transducer material and the probes have been successfully used on the testing of thin sheet, thin-walled tube and bridge-mandrel extrusions, as well as the whole range of welded sheet and tube from $\frac{1}{8}$ in. upwards. Flaws have been detected in extruded aluminium tubes of 0.060 in. wall thickness. Other new probes include low frequency probes which use barium titanate discs with a resonant frequency of 400 kc/s. as the transducer material, and are intended for use on porous and coarse grained materials such as refractory blocks and cast alloys. The variable angle transverse wave probes have been designed to enable the ultrasonic beam to be directed into the specimens at any angle between 0 and 50° to the surface. Among the advantages claimed for these steerable beam probes are the facility for rapid determination of the orientation of flaws; the fact that the angle of the beam can be varied enables these probes to replace the wide range of fixed angle probes necessary for a complete search of the specimens;



The Ultrasonoscope.



Edwards vapour booster pump.

and the fact that a wide area can be searched from one surface position.

Corrosion Meetings in Frankfurt

In order to meet the general desire to reduce the time spent at scientific meetings to a minimum, it has been decided to hold the Corrosion Meeting 1954 and the Dechema Annual Meeting 1954 simultaneously, and with the participation of the European Federation of Chemical Engineering, from November 11th to 13th in Frankfurt a.M. This function will mark the resumption of the series of corrosion meetings, the last of which was held in Frankfurt a.M. in 1943. The meetings are sponsored by the Arbeitsgemeinschaft Korrosion (Corrosion Group) which consists of eight German technical and scientific societies.

Many important advances have been made in all countries since 1943, in research on corrosion phenomena and in the methods of preventing damage caused by corrosion. The object of the meeting is to present a report on this subject and to stimulate new developments.

"The Nature and Causes of Corrosion" is the main theme of ten papers to be read on November 11th, and "Processes for the Prevention of Corrosion" will be the subject for ten other papers to be presented on November 12th. The lectures, which will be given by well-known personalities in the field of science and industry in Germany and abroad, will deal with the following problems: the scientific principles of corrosion phenomena and of inhibition; the relationship between electro-chemistry and corrosion; the behaviour of certain materials under corrosion conditions; the effect of certain aggressive agents; and finally, the importance of various methods of protection from corrosion, such as paints, phosphating, cathodic protection and the use of plastics.

An opportunity of visiting a number of industrial works in the Frankfurt district will be provided on November 13th.

The meetings are being arranged and organised by DECHEMA, Deutsche Gesellschaft für chemisches Apparatewesen, Frankfurt a.M.-West 13, P.O. Box.

